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Volume 57 Number 1 February 1975

Articles

Notes

Publications

Books Reviewed

Books Received 148

News

Announcements 150

Personnel 151

Obituaries 154

David A. Clarke, Jr., 1919–1974; Rex Warfield Cox, 1888–1974.

Institutional Members 155

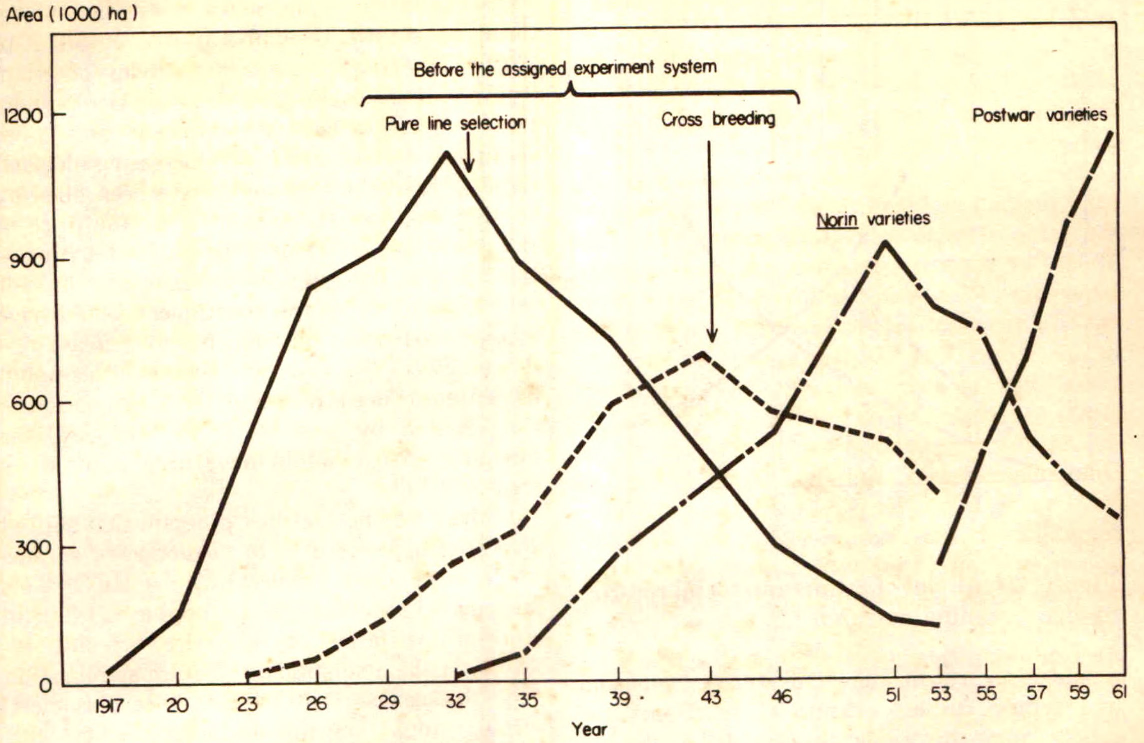

Figure 1. Changes in area planted in the improved varieties of rice, 1917–1961

Source: Japan (1952; 1954–61) and Nogyo Hattsushi Chosakai.

the National Experiment Station was given the responsibility of conducting the initial crossing up to the selection of the first several filial generations. The regional breeding centers, in each of eight regions, conducted further selections so as to achieve adaptation to the regional ecological conditions. The varieties selected at the regional stations were then sent to prefectural stations to be tested for acceptability in specific localities. The varieties developed by this system were called Norin (abbreviation of Japanese words for the Ministry of Agriculture and Forestry) varieties. This system was highly successful, and the Norin varieties spread rapidly, especially after 1935 (fig. 1).

The experiment station system was modified again in 1950. Local experiment stations began to conduct independent cropbreeding programs from the first step of artificial crossing. This change reflected the increase in the capacity of local agricultural experiment stations that enabled them to breed the varieties more specifically designed to satisfy local demand.

The rice breeding research that we analyze in this study is limited to the research for 1904–50. In 1904 the scientific cropbreeding program was initiated. The rice research since 1950 based on the new system is excluded, because its impact has not yet been fully realized. We conduct separate analyses for the periods before and after the start of the Assigned Experiment System in order to evaluate the impact of the organizational innovation on social productivity.

MODEL OF ESTIMATING SOCIAL RETURNS

We here develop the theory and the method of estimating the social benefit from rice breeding research and its distribution in society, first with the assumption of market equilibrium in a closed economy. Later, we try to incorporate into the model the implications of rice imports and government policy.

Using the Marshallian concepts of social welfare and cost, social returns to rice breeding research are measured in terms of changes in consumers' and producers' surpluses resulting from the shift in the rice supply curve corresponding to a shift in the rice production function.[1] This relation is shown in figure 2 in which

[1] In this study producers' surplus is defined as the

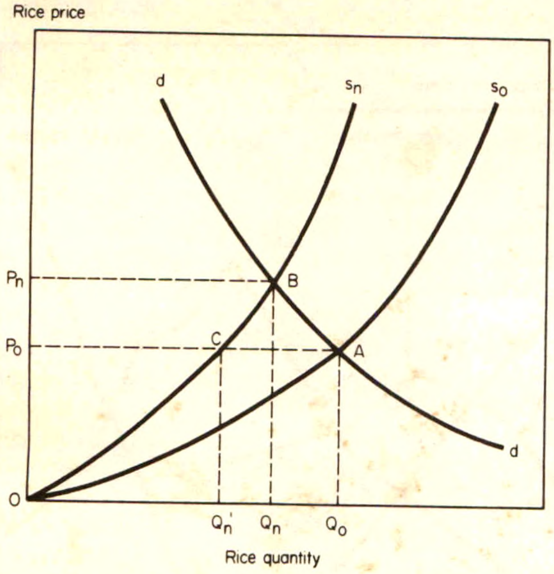

Figure 2. Model of estimating social returns to rice breeding research

d and s_o represent the actual market demand and supply curves, whereas s_n represents the supply curve that would have existed if the improved rice varieties were not developed.

Assuming market equilibrium and no rice import, the shift in the supply curve from s_n to s_o would increase consumers' surplus by area ABC + area BP_nP_oC, the producers' surplus by area ACO — area BP_nP_oC, and social benefit by area ABC + area ACO.

However, during the period of analysis, Japan remained a net importer of rice. The rice import was regulated by the government by tariffs and quotas. As discussed previously, the basic motive of the government was to maintain a stable price level for rice so as to prevent a rise in the cost of living of urban workers. In fact, a stable trend for the price of rice relative to the general price index was maintained in the course of modern economic growth in Japan until around 1960 when it began to rise sharply after the dramatic change in rice policy towards the protection of producers (Hayami). In spite of occasional price support operations, the actual level of rice prices in Japan before 1960 should have been below the market equilibrium in autarky.

total value output in agriculture minus the payment to the inputs applied to agricultural production that are supplied from nonagriculture; the "surplus" includes not only the entrepreneurial profit of farmers but also land rent, wages to family labor, and returns to farm capital.

Assuming the basic policy motivation of securing a sufficient supply of rice in order to prevent the rise in the cost of living of urban workers, if the increase in domestic rice production due to varietal improvement and other means could not meet the increasing demand requirements, the gap would have been filled by the imports. Let P_o in figure 2 be the price of rice that the government determined to maintain. If the domestic supply schedule did not shift from s_n to s_o, the government would have manipulated policy instruments to increase rice import by $Q'_n Q_o$. Then producers' surplus would have been reduced by area BP_nP_oC without being compensated by area ACO. In this case, the foreign exchange would have been reduced by area ACQ'_nQ_o.[2]

If there was no breeding program that shifted domestic supply from s_n to s_o, producers' surplus would have been smaller by area ACO. This area may be defined as the producers' gain in economic welfare from the rice breeding research on the assumption of a price stabilization policy by means of rice import. Since consumers' surplus would remain unchanged under this assumption, the producers' gain would be equivalent to the total social benefit produced from the rice breeding programs. Another contribution of the breeding research to the national economy in the open economy case would be the gain in foreign exchange by area ACQ'_nQ_o.

In reality, in spite of the efforts to shift the rice production function upwards, domestic supply could not keep up with the expansion in demand, resulting in rice imports in the order of 5% to 20% of domestic production. Therefore, s_o in figure 2 would have been located somewhere to the left of A if we define A as the point of equilibrium of total market supply and demand. However, this does not require modification of our model.

MODEL FOR QUANTITATIVE ESTIMATION

The first step in estimating the changes in consumers' and producers' surpluses is the specification of the demand and supply schedules. In this study a constant elasticity demand function is assumed as

$$q = H\, p^{-\eta},$$

where q and p are respectively the quantity and the price of rice, and n is the price elasticity of

2 Actually the foreign exchange earning also depends on the world price of rice. (See footnote 7.)

Articles

EFFICIENCY AND EQUITY IN PUBLIC RESEARCH: RICE BREEDING IN JAPAN'S ECONOMIC DEVELOPMENT

MASAKATSU AKINO and YUJIRO HAYAMI

Research contributes to the public good and public support is required in order to attain a socially optimum level of investment in research. However, the extremely high rate of returns to rice research in Japan provides evidence that an underinvestment in agricultural research is typical. Financing rice research out of government tax revenue is rationalized in terms of its contribution to the national goal of economic development.

Key words: agricultural research, public goods, consumers' and producers' surpluses, foreign exchange.

Research is an activity which requires scarce resources to produce new information or knowledge useful to society. The information produced from research is typically endowed with the attributes of the "public good" of the Samuelson-Musgrave tradition: (*a*) nonrivalness or jointness in supply and utilization and (*b*) nonexcludability or externality (Samuelson 1954, 1955, 1958; Musgrave; Arrow). Nonrivalness is the very nature of information since there is no capacity limit to its utilization. Also, in general it is difficult (or costly) to exclude from the use of information those who do not pay for it, although there have developed institutions, such as the patent laws, which make certain kinds of information excludable.

Given such attributes of the research product, a socially optimum level of investment in research can hardly be expected if it is left to private firms. Public support is required in order to correct the failure of the market mechanism to allocate resources to research activities. In organizing public investment in research, relevant considerations should be both efficiency and equity in terms of social welfare. Efficiency should involve the magnitude of the social rate of returns to the investment, and equity should involve the question of who captures the gain (and bears the loss) from it.

In this paper we attempt to analyze these two problems concerned with public resource allocation to research and development, using as a case the experience of the rice breeding program in Japan in the course of her modern economic growth. We employ the approach developed by Griliches and others (Ayer and Schuh; Peterson; Schmitz and Seckler) to estimate (*a*) the social rate of returns to public investment in rice breeding research and (*b*) the distribution of the returns among producers and consumers, both in the case of autarky and in the case of an open economy where rice imports are allowed. In the latter case the contribution of the research program to foreign exchange earnings also is analyzed.

Although the model we employ is static, we will develop our analysis within the context of economic development and discuss the implications of the results of this case study for the problem of public resource allocation in developing countries.

RICE AND RICE RESEARCH IN ECONOMIC DEVELOPMENT

We present a brief historical sketch of the role of rice and rice research in the modern economic growth in Japan since the last quarter of

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the nineteenth century as background knowledge for the analysis that follows. (For the role of rice in Japan's economic development, see Hayami. For the history of agricultural research in Japan, see Hayami and Ruttan [1971, pp. 153–64] and Hayami and Yamada.)

Rice has been the most important agricultural product in Japan, comprising 40 to 60% of the value of total agricultural output. The role of rice in food consumption has been equally important. Rice was the source of more than 60% of the total caloric intake of the Japanese before World War II. It was only in the late 1960s that the share of rice in the total caloric intake dropped below 40%. The share of rice in the consumption expenditures of urban blue collar workers continued to be as high as 30% until 1930. Despite rapid postwar economic growth, the share of rice in the consumption expenditure of urban worker households did not drop below 10% until after 1960 (Hayami).

Given such a predominant weight of rice in the consumption expenditure of urban workers, a rise in the price of rice should have contributed significantly to a rise in their cost of living, particularly for those at the lower income levels. As a result, higher rice prices added to general inflationary tendencies and to the pressure for wage increases. The increase in the supply of rice to meet the growing demand from the urban sector was not only critical for the welfare of urban dwellers, but was also important for the industrial development of Japan, especially in its early stages when labor-intensive light industries (such as textiles) predominated and the rise in the wage rates had a significant impact on the returns to capital.

Given the national goal of Japan to "catch up" to the Western powers through industrial development, it is plausible that the rice policy was designed to increase the supply of rice, which could hold down the rise in the cost of living of urban workers. Of course, the rice supply may be augmented by imports from abroad. In fact, the government manipulated tariffs and quotas as the major means of achieving the long-term stability of rice prices observed since Japan became a net importer of rice at the beginning of this century. However, the reliance on rice imports would have resulted in a drain on foreign exchange needed for the import of capital goods and technical know-how critical for development.

Thus, a requisite for the industrialization and economic growth of Japan was an increase in the domestic supply of rice consistent with the demand expansion. However, Japan already was densely populated at the beginning of modern economic growth, and there was little room to expand the cultivated area. The possibility of increasing paddy field area was even more severely limited. Thus, an expanding demand for rice would have to be met by raising yield per unit of paddy field area. The basic approach to increasing the rice yield was to develop and diffuse high yielding varieties of rice, responsive to heavier applications of fertilizer (Hayami and Ruttan 1971; Ogura). Responding to this need, the government began from the 1880s to organize rice research by establishing agricultural experiment stations.

The history of the rice breeding research since the establishment of the National Agricultural Experiment Station in 1893 may be divided into four periods: (*a*) 1893 to 1903, (*b*) 1904 to 1925, (*c*) 1926 to 1949, (*d*) 1950 to present. The first covers the period before the start of scientific rice breeding programs. During this period, the experiment station was in its infancy, conducting primarily simple field experiments that compared yield performances of the various varieties of crops or various cultural practices.

The second period was characterized by rice breeding research based on pure line selection. The scientific rice breeding program began with the application of the crossbreeding technique in 1904, but it took almost two decades before new varieties of major practical significance were developed by this method. In constrast, the rice breeding programs that applied the method of pure line selection brought about quicker practical results. However, the potential of yield increase by this technique was exhausted as the purity of strains was raised to a limit.

Meanwhile, as experience and knowledge of the crossbreeding method were accumulated, the area planted in the varieties developed by this method increased sharply after 1920 (fig. 1). The major problem in the application of this method was the shortage of expert breeders who were able to handle the initial crossing that required particularly high quality work. In order to solve this bottleneck, a nationwide coordinated cropbreeding program called the "Assigned Experiment System" (the system of experiment assigned by the Ministry of Agriculture and Forestry) was established in 1926; this marked the beginning of the third period. Under the Assigned Experiment System

demand. Similarly, a constant elasticity supply function is assumed as

$$q = G\,p^{\gamma},$$

where γ is the price elasticity of rice supply. We assume a hypothetical supply curve that would have existed in the absence of improved varieties as

$$q = (1 - h)G\,p^{\gamma},$$

where h represents the rate of shift in the supply function due to varietal improvement. In competitive equilibrium the supply function is equivalent to the marginal cost function derived from the production function. Since the relation between the rate of shift in the marginal cost function (h) and the rate of shift in the production function (k) can be approximated by

$$h \approx (1 + \gamma)k,$$

the following approximation formulas hold in equilibrium:

$$\text{area } ABC \approx \frac{\tfrac{1}{2}p_o q_o[k(1+\gamma)]^2}{\gamma+\eta}$$

$$\text{area } AOC \approx k p_o q_o$$

$$\text{area } BP_nP_oC \approx \frac{p_o q_o k\,(1+\gamma)}{\gamma+\eta} \times \left[1 - \frac{\tfrac{1}{2}k(1+\gamma)\eta}{\gamma+\eta} - \tfrac{1}{2}k(1+\gamma)\right]$$

and

$$\text{area } ACQ'_nQ_o \approx (1+\gamma)\;k p_o q_o.$$

For the derivation of the above formula, the neutral shift in the production function is assumed primarily for the ease of manipulation.

PARAMETERS AND DATA

In order to estimate the social returns from the rice breeding research by the model developed in the previous section, we have to specify the price elasticities of demand and supply (η and γ), the rate of shift in production function (k), and the value of rice output ($p_o q_o$). In addition, we need the data for research costs in order to calculate the social rate of returns to rice breeding research.

The estimate of the price elasticity of demand for rice (η) is available from Ohkawa's classical study. His estimates were based on household survey data of 1931–38 for the urban population, and on 1920–38 market data for the rural population. The estimates differ for different occupational, regional, and income groups, but they cluster around 0.2. We will adopt 0.2 for η.

The price elasticity of rice supply (γ) was estimated by Hayami and Ruttan (1970) on the basis of 1890–1937 time-series data, and by Yuize on 1952–62 time series. The results of the former study indicates that γ was in the vicinity of 0.2, and those of the latter range from 0.2 to 0.3. We will here adopt 0.2 for γ.

Although the relative magnitudes of the changes in consumers' and producers' surpluses are critically dependent on the choice of specific values for η and γ, social benefit defined as the change in total economic surplus (area ABC + area AOC) is not so sensitive to the choice of those parameters since k is a small fraction of output (it is, in fact, smaller than 4%). For $k = 0.04$ and $\eta = 0.2$, (area ABC + area $AOC)/kp_oq_o$ is calculated as 1.10 for $\gamma = 0$, 1.07 for $\gamma = 0.2$, and 0.99 for $\gamma = \infty$; for $k = 0.04$ and $\gamma = 0.2$, it is 1.14 for $\eta = 0$, 1.07 for $\eta = 0.2$, and 1 for $\eta = \infty$. Therefore, any possible error in the estimate of social benefit would be within 10% for both positive and negative directions.

We estimated the rate of shift in the aggregate rice production function (k) by averaging the yield differences between the improved and the unimproved varieties for the same level of inputs, using the areas planted in the improved varieties as weights (table 1).[3] The data for the yield differences between the improved varieties and the varieties that were replaced by the improved varieties at the same level of inputs are based on the results of the comparative yield tests at various agricultural experiment stations (Japan 1893–1938; 1926; 1935; 1952; 1953b; 1954–61; 1955).[4]

Data for the value of rice output ($p_o q_o$) are obtained by valuing the physical outputs of rice

[3] To a large extent k_t depends on the ratio of area planted in the improved varieties developed by the rice breeding programs. Declines in k_t since the late 1930s in the case of pre-Assigned Experiment System and since the early 1950s in the case of Assigned Experiment System reflect the replacement of the varieties developed in respective systems by those developed in succeeding systems.

[4] The k_t thus calculated would likely involve an underestimation bias in the estimation of the contribution of breeding research to rice production. The assumption that underlies our method of calculating the k_t is the neutrality in the shift of rice production function. However, the improved varieties are usually more responsive to fertilizers, and their yield margins over the unim-

Table 1. Estimates of the Average Rate of Shift in Rice Production Function (k) due to Varietal Improvement in Japan

Period	Before the Assigned Experiment System	Under the Assigned Experiment System
	(%)	
1915–1919	0.09	
1920–1924	0.85	
1925–1929	2.01	
1930–1934	2.76	0.06[b]
1935–1939	2.91	0.32
1940–1944	2.78	0.75
1945–1949	2.09	1.27
1950–1954	1.43[a]	1.70
1955–1959		1.05
1960–1961		0.66

[a] 1950–53 average.
[b] 1932–34 average.

by the 1934–36 average price (Yamada and Hayami). The years 1934–36 are generally used as the basis of index construction in Japan because "normal" price relations prevailed during this period.[5]

Data for the expenditure on rice breeding research before the Assigned Experiment System are not readily available. There is an estimate that the ratio of expenditure on crop breeding programs to the total expenditure of agricultural experiment stations in 1927 was 43% for the national experiment stations and 45% for the prefectural experiment stations (Oda). We estimated the annual expenditures for rice breeding research by multiplying those ratios to the total expenditures of the national and prefectural stations (Hara and Kawabe; Japan 1893–1938; Japan 1963; Zenkoku Nogyō Shikenjocho Kai).

Expenditures for research under the Assigned Experiment were financed by the central government, and those data are readily available (Japan 1953a). In addition to the expenditures covered by the central government, prefectural governments paid for the costs of the tests of local adaptability of the Norin varieties and of the multiplication of improved seeds. Those expenditures by the local governments were estimated by multiplying the expenditures for crop breeding programs in the prefectual experiment stations by the ratios of area planted in the Norin varieties to area planted in total improved varieties. (Japan 1952; Japan 1953b; Japan 1954–61; Nogyo Hattatshushi Chosakai).[6] The time series of the expenditure on crop breeding programs, thus estimated, were deflated by the consumers price index with 1934–36 set for 100.

QUANTITATIVE FINDINGS

Distribution of Social Benefit

Estimation of the social benefit was conducted separately for the breeding programs before the Assigned Experiment System and for the programs under that system. The results are summarized in table 2.

In the autarky case, the most remarkable results are that the consumers were the sole beneficiaries of the research and that the producers were made worse off. Such results were derived from the application of low price elasticities of demand and supply. In particular, the demand elasticity plays a decisive role in the distribution of benefit among consumers and producers.

If the price elasticity of demand is infinitely elastic, the social gain from the shift in supply would be totally captured by the producers. In contrast, if it is zero there should be no gain to producers so far as supply is competitive. If the producers have the power of monopolistic pricing, they should be able to capture the major share of the welfare gain by taking advantage of the inelastic demand. However, such a possibility does not exist in the case of agriculture characterized by near perfect competition with a mass of small producers.

In reality, however, Japan did not operate in the condition of rice autarky during the period of this analysis. Assuming the basic motivation of the government policy was the stabilization of rice prices by means of rice import, the producers would have been made further worse off

proved varieties increase for the higher levels of fertilizer application. The assumption of neutral technical progress would result in a bias in the estimation of the shift in production function to the extent that the positive interaction effects between varietal improvement and fertilizer application were neglected.

[5] The price of rice relative to the prices of other commodities was somewhat lower during this period, due to the large inflow of rice from other countries, Korea and Taiwan, although the government tried to support the price of rice by increasing the government inventory. The valuation of output by the 1934–36 average price might result in an underestimation of the stream of social benefit.

[6] Those estimates of the expenditure on crop breeding programs include not only the cost of research and development but also the cost for extension such as the multiplication of seeds. Also, our cost data overestimate the cost of rice breeding research because the breeding programs include not only rice but also *mugi* (wheat, barley, and naked barley) although the weight of rice research in the programs should have been predominant.

Table 2. Estimates of Average Annual Benefit in Japan from Rice Breeding Research (million yen in 1934–36 constant prices)

	Autarky Case			Open Economy Case	
Period	Producers' Gain (1)	Consumers' Gain (2)	Total Social Benefit (3) = (1) + (2)	Total Social Benefit = Producers' Gain (4)	Saving of Foreign Exchange (5)
Before the Assigned Experiment System:					
1915–1919	− 2.86	4.29	1.43	1.43	1.71
1920–1924	− 26.75	40.48	13.73	13.49	16.19
1925–1929	− 64.55	98.58	34.03	32.86	39.43
1930–1934	− 89.86	138.20	48.34	46.07	55.27
1935–1939	−101.74	156.67	54.93	52.22	62.67
1940–1944	− 90.56	139.29	48.73	46.43	55.72
1945–1949	− 68.02	103.97	35.95	34.66	41.59
1950–1953	− 47.94	72.84	24.90	24.28	29.14
Under the Assigned Experiment System:					
1932–1934	− 2.03	3.05	1.02	1.02	1.22
1935–1939	− 11.56	17.38	5.82	5.79	6.95
1940–1944	− 24.92	37.62	12.70	12.54	15.04
1945–1949	− 41.90	63.58	21.68	21.19	25.43
1950–1954	− 56.64	86.29	29.65	28.76	34.51
1955–1959	− 45.27	68.57	26.30	22.86	27.42
1960–1961	− 30.65	46.23	15.58	15.41	18.48

by area AOC as measured in table 2, if there were no program for the rice breeding research. Thus, rice research preserved a larger share of the Japanese rice market for domestic producers. Without the research the Japanese economy would have lost foreign exchange by area ACQ'_nQ_o.

In fact, as the estimates in table 2 indicate, the possible loss in foreign exchange due to the shortage of domestic rice supply during the 1930s would have amounted to about 5% of total imports.[7] Considering the chronic shortage of foreign exchange in the course of industrialization in Japan, the contribution of the rice breeding research to economic growth should have been significant.[8]

[7] It should be more appropriate to estimate the saving of foreign exchange according to the method of Bruno and Krueger in terms of the saving of rice import measured in world prices minus foreign exchange requirements for rice breeding programs. However, the application of such a method will not cause any significant change in the results, because the difference between the domestic and world prices of rice before 1960 did not exceed 10%. The foreign exchange requirements for rice breeding projects should be negligible.

[8] However, it is difficult to estimate the gain in national economic welfare due to the saving of foreign exchange in a term which is comparable with consumers' or producers' surplus.

In the open economy case, the producers were made better off by the rice breeding research, while consumers continued to enjoy the same level of economic welfare without causing a drain on foreign exchange. In reality, however, the same level of consumers' welfare may not have been secured in the absence of the shift in the domestic rice supply schedule due to the breeding research, since the constraint of foreign exchange may not have allowed the large additional rice imports. The autarky and the open economy cases in our analysis represent the polar cases within which reality lies.

The Social Rate of Return

In order to assess the efficiency in resource allocations to rice breeding research, both the external and the internal rates of returns are calculated. The external rate of return (r_e) is defined as the rate calculated from the following formula:

$$r_e = \frac{100(iP + F)}{C},$$

where i is the external rate of interest, P is the accumulation of past returns, F is annual future returns, and C is the accumulation of past research expenditures. The external rate of in-

terest (i) is applied to the accumulation of both returns and expenditures. In this study 10% is assumed for the interest rate.

The internal rate of return (r_i) is the rate that results in

$$\sum_{t=0}^{T} \frac{R_t - C_t}{(1 + r_i)^t} = 0,$$

where R_t is the social benefit in year t, C_t is the research cost in year t, and T is the year that the research ceases to produce returns.

The social rates of returns for the breeding programs before the Assigned Experiment System are calculated for two alternative cases: case A assuming that the net returns ($R_t - C_t$) in 1935 would have been maintained forever from that year and case B assuming that the net returns would become zero after 1953. Case A represents a polar case that the knowledge and experience accumulated in a breeding program would continue to be utilized even after the varieties developed by the program were replaced by the varieties developed by the subsequent breeding programs, whereas case B assumes that the life of the varieties ends when they are replaced by the new ones.

In calculating the rates of return in the programs under the Assigned Experiment System, two alternative assumptions were made as to the stream of returns: case A assuming that the net returns would have continued to be maintained forever at the level of 1951 from that year when the area planted in the Norin varieties reached a peak and case B assuming that the net returns would have become zero after 1961.

The results of estimation of the social rates of return, both for the autarky and the open economy cases, are reported in table 3. In terms of the magnitude of the social rates of return there are only small differences between the two cases. Both results indicate that the crop breeding research represents a lucrative public investment opportunity.

The estimates of the rate of return for the rice research before the Assigned Experiment System are comparable in magnitude with those for the hybrid corn research in the United States reported by Griliches (about 35% for the internal rate and 700% for the external rate) and those for the poultry research in the United States by Willis Peterson (about 20% for the internal rate and 140% for the external rate). The estimates for the programs under the Assigned Experiment System are comparable with those for the cotton research in San Paulo, Brazil, reported by Ayer and Schuh (about 90% for the internal rate) and from wheat research in Mexico by Barletta (about 75% for the internal rate). Judging from those estimates, gross underinvestment in the varietal improvement research has been pervasive among both developed and developing countries.

Table 3. Estimates of the Social Rates of Returns to Rice Breeding Research in Japan (million yen in 1934–36 constant prices)

	Autarky Case		Open Economy Case	
	Case A	Case B	Case A	Case B
Before the Assigned Experiment System				
External rate				
(1) Net cumulated past returns	985.88	7,660.95	952.52	7,392.64
(2) Past returns expressed as an annual flow	98.58	766.09	95.25	739.26
(3) Net annual future returns	44.63	0	42.41	0
(4) Total net annual returns, (2) + (3)	143.21	766.09	137.66	739.26
(5) Cumulated past research expenditures	123.39	783.47	123.39	783.47
(6) Rate of return, 100 (4)/(5)	166%	98%	112%	94%
Internal rate	27%	25%	26%	25%
Under the Assigned Experiment System				
External rate				
(1) Net cumulated past returns	487.98	1,639.77	480.11	1,610.65
(2) Past returns expressed as an annual flow	48.79	163.97	48.01	161.06
(3) Net annual future returns	31.73	0	30.67	0
(4) Total net annual returns, (2) + (3)	80.52	163.97	78.68	161.06
(5) Cumulated past research expenditures	14.51	46.78	14.51	46.78
(6) Rate of return, 100 (4)/(5)	554%	350%	542%	344%
Internal rate	75%	73%	75%	73%

The results in table 3 show that the social rate of return was increased after the crop breeding programs were reorganized into the Assigned Experiment System. This seems to suggest that efficiency in research was improved by the institutional innovation that enabled the conflict between the constraint of research resources and the need for location-specific breeding research to be solved by organizing a division of labor among the national and the prefectural experiment stations. We do not deny the possibility that the increase in the rate of return over time reflects the scale economies inherent in the process of research in producing knowledge and information. (The hypothesis on the scale economies in the research production function was suggested by Schultz [pp. 150–52] and was supported by Evenson.) However, if there were no organizational improvements that enabled the better coordination of the enlarged research complex, the increase in the efficiency of rice breeding research would not have been as dramatic as measured in this study.

IMPLICATIONS

Finally we discuss the implications of the results of this case study for the problem of public resource allocation with special reference to economic development in the developing countries.

As discussed previously, because of the public good attributes of the product of research, public support is required in order to attain a socially optimum level of investment in research. This study of rice breeding in Japan adds to the evidence that an underinvestment in research is typical. If underinvestment in agricultural research was the case for Japan, as well as for the United States (as suggested by Griliches and others), both characterized by a relatively well established agricultural experiment system, the potential benefit from the research for the developing countries where the public research system is in an early stage should be extremely large. This inference is consistent with the findings of very high social returns from the cotton research in Brazil and the wheat research in Mexico. Public planners and policy makers should be constantly reminded about the tendency to underestimate the social productivity of research.

That the product of research is endowed with the attributes of a public good does not necessarily mean that the investment in research should be financed out of government tax revenue. If the major share of the gain would be captured by the producers, it might be more appropriate in terms of equity criteria to let the group of producers finance the investment themselves. However, as the results of our analysis suggest in the assumption of autarky, the investment in research in such commodities as rice, characterized by low price elasticities of demand and supply, often results in an increase in consumers' welfare and a sacrifice in producers' benefit. In such a case research should be funded by the government.

The results based on the autarky assumption, though unrealistic in the case of Japan, should be relevant to developing countries such as Taiwan characterized by self-sufficiency of food staples. In fact, as the study by Lee shows, a major source of resource outflow from agriculture to nonagriculture in Taiwan was the deterioration of the internal terms of trade against agriculture corresponding to the remarkable increase in agricultural productivity. Agricultural research (and extension) can be utilized as a system of resource transfer from agriculture to nonagriculture for financing industrial development. To some extent, the above discussions would also hold for the major exporters of food staples, such as Thailand, which face relatively inelastic world demand.

If we assume a food policy of controlling food imports in order to keep food prices low for urban workers so as to facilitate industrial capital accumulation and development, research that shifts the food production function upwards would partially compensate for the decline in producers' surplus due to the imports. In addition, it would contribute to the national economy as it enables the saving of foreign exchange needed for the import of technical knowhow and capital goods. These appeared to be the critical contributions of the rice breeding research to the modern economic growth in Japan. And Japan's experience may be highly relevant to today's developing countries (such as India) which have to rely on the import of food staples.

Finally, Japan's experience with respect to the increase in the social rate of return to research investment corresponding to the reorganization of the rice breeding system should also be relevant. Public funds for economic development are scarce in developing countries. Competent scientists and technicians who can carry out the significant research programs are equally scarce. How to economize the scarce research resources is an especially serious problem for the design

of research organization in the developing countries. Institutional innovations such as the Assigned Experiment System in Japan could be critical if the extremely large potential demand for research resources are to be met by those countries' limited capacities.

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THE SOCIAL PROFITABILITY OF SUBSIDIES FOR AGRICULTURAL EXPORTS: THE CASE OF GHANA

WALTER HAESSEL and EDWARD VICKERY

A framework is developed to estimate the social profitability of export subsidies. The approach indicates whether a definite gain has been obtained even though the new equilibrium is not a first best. A method is provided for measuring consumer surplus when the demand curve shifts as a consequence of the policy. The technique is applied to selected agricultural exports from Ghana. It is found that while the subsidies would be profitable there would also be a heavy fiscal burden associated with the subsidies even though the subsidy scheme may be partly self-financing.

Key words: export subsidies, LDC exports, social profitability, Ghana.

Many less developed countries maintain an exchange rate which often causes them to run a deficit on the balance of trade and/or current account. Devaluation is usually considered to be a politically unacceptable solution due to the adverse effects on the domestic price of imported capital and consumer goods. Curbing imports through higher tariffs is ruled out for the same reason. Quotas, restrictions on imports, and various controls on the use of foreign exchange are instruments frequently used in these situations. The quotas and restrictions are then combined with domestic price controls. We shall consider a method of estimating the increase in social welfare that can result from a system of export subsidies in an economy with the foregoing constraints, a method which we shall then apply to some traditional agricultural exports in Ghana.

The net improvement in social welfare as a result of instituting such policies is the relevant criterion.[1] Producing additional commodities for export involves a reduction in consumer surplus as well as utilization of resources which could be employed in alternative projects. By contrast, a naive criterion of maximizing foreign exchange earnings would result in a lower level of social welfare. We shall also demonstrate that a policy of export subsidies can be socially desirable even though in certain cases it may result in decreased foreign exchange earnings on some commodities. For the typical crop, however, foreign exchange earnings will increase.

First we shall discuss the theoretical framework and the method of empirical approximation, including a method of estimating consumer surplus when a shift occurs in the demand curve—a discussion which, to the best of our knowledge, has never appeared in the literature. Secondly, we use Ghanaian data to estimate the approximate magnitude of the change in social welfare which could be expected from implementing the recommended export subsidies, and finally we discuss the fiscal implications of such policies.

THEORETICAL FRAMEWORK

The General Case

We begin with the discussion of a subsidy on one crop only and then generalize this to multiple subsidies. Following Harberger, the net social benefit (NSB) to the economy of a particular policy can be measured by the change in the total of collective consumers' and producers' surplus. Thus the NSB of an export subsidy of ΔP_j on commodity j can be expressed as

$$(1)\ \Delta W_j = \sum_{i \epsilon I_j} \int_0^{\Delta P_j} [D_i(Z_j)\partial X_i/\partial Z_j]dZ_j,$$

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[1] By improvement in social welfare we mean the excess of social benefits over social costs attributable to any given policy.

where D_i represents the excess of marginal social benefit (MSB) over marginal social cost (MSC) per unit of activity i, X_i the number of units of activity i, Z_j the policy variable (export subsidy in this case), and I_j the set of all activities in the economy with divergences between MSB and MSC whose levels of activity are affected by the policy change.

In this particular problem two types of divergences are worthy of consideration, a divergence between the social opportunity cost (SOC) of labor and the wage rate and a divergence between the official exchange rate and the marginal social value of foreign exchange which is calculated to take existing tariffs into account. Regarding the possibility of the former divergence, Ghana is not a labor surplus economy, especially in the rural areas with which we are primarily concerned (Addo; Rourke). Hence the rural wage rate is an accurate reflection of the SOC of rural labor. However, the industrial wage probably exceeds the SOC of industrial labor in view of the widespread urban unemployment in Ghana (Williams and Ntim). A policy of agricultural export subsidies is unlikely to have any substantial effect on the level of industrial employment and such changes are presumably negligible.[2] In the event that the subsidies increase the level of industrial employment or the SOC of rural labor is below the rural wage rate (for example, if additional rural employees came from the urban unemployed), then our measure of the social benefits would be an underestimate of the true social benefits.[3]

As to the divergences resulting from an overvalued exchange rate, equation (1) indicates that to appraise the NSB of a subsidy on commodity j, any activity involving foreign exchange, whether export or import, whose level will be affected by the subsidy must be taken into account. Two types of activities fall into this class; factors of production which are imported and other "tradeable" commodities. The import content of production factors are explicitly taken into account in computing the level of subsidy through shadow pricing of production costs. We define a tradeable commodity for Ghana as one which Ghana produces, exports and/or imports, or produces but does not trade due to the lack of an optimum export subsidy.[4] The tradeable commodities whose production levels are likely to be affected are other agricultural commodities which compete with commodity j for resources such as land and labor. Hence, we concentrate only on agricultural commodities.

Let J denote the set of all tradeable agricultural commodities. Define I'_j as the subset of I_j not in J. Thus, I'_j is the set of activities whose level changes when commodity j is subsidized to offset the divergences between social and private costs because of the overvalued exchange rate (i.e., the imported inputs required in the production of commodity j). If an export subsidy is placed on all commodities in J, the NSB of the set of subsidies is given by

$$(2)\quad \Delta W = \sum_{j\epsilon J} \int_0^{\Delta P_j} [D_j(Z_j)\partial X_j/\partial Z_j]dZ_j + \sum_{j\epsilon J} \sum_{i\epsilon I'_j} \int_0^{\Delta P_j} [D_i(Z_j)\partial X_i/\partial Z_j]dZ_j.$$

The first term on the right side of equation (2) is a measure of the direct NSB of the subsidies arising from the changes in consumption, production, and export levels, while the second is a measure of the NSB arising from changes in the level of imported resources. The latter set of divergences will be taken into account by shadow pricing imported resources when evaluating the direct benefits.[5] Let P^*_j be the appropriate level of subsidy that takes account of

[2] See Szereszewsky for evidence that the linkages between agriculture and other sectors of the Ghanaian economy are weak.

[3] If X_k is the level of nonagricultural employment, we are in essence assuming $\partial X_k/\partial Z_j = 0$. If this is not the case, the bias (actual measure minus true measure) would be given by

$$B = -\int_0^{\Delta P_j} [D_k(Z_j)\partial X_k/\partial Z_j]dZ_j.$$

Since we expect $D_k > 0$ (i.e., the nonagricultural wage exceeds the SOC of nonagricultural labor), B would be of the opposite sign of $\partial X_k/\partial Z_j$ which will probably be positive if it is not zero. For example, an increased demand for the processing of additional commodities for export and increased transport requirements would result in $B < 0$. It is difficult to think of cases which lead to biases in the opposite direction.

[4] Logically, this category should also include commodities which are not being produced in Ghana but which could be produced for export (if justified by the appropriate export subsidy) or local consumption (if current imports had the appropriate tariff). In addition, commodities which are being produced for domestic consumption behind a tariff wall but which would be imported if the tariff was reduced to the appropriate level should be included.

[5] By shadow pricing foreign exchange, the second term is incorporated into the first by adjusting the D_j for other divergences. See Harberger (pp. 789–91) for a convincing discussion.

imported resources. Then equation (2) can be rewritten as

$$(3)\ \Delta W = \sum_{j \epsilon J} \int_0^{P^*_j} [D_j(Z_j)\partial X_j/\partial Z_j] dZ_j.$$

Estimating the NSB of Export Subsidies

We shall discuss a method for approximating equation (3) empirically when the only significant divergences between social and private costs on the one hand and social and private returns on the other arise in the foreign exchange market. We define the following notation:

R = official exchange rate (local currency-price of foreign exchange);
R_s = social opportunity cost (in local currency) of foreign exchange;
$r = (R_s - R)/R$ = proportion by which the currency is overvalued by the official exchange rate;
P_{oj} = existing domestic wholesale price of commodity j at the normal port of export (which is assumed to equal marginal private costs of production);
P_{wj} = existing f.o.b. world price of commodity j (in foreign currency) at the normal port of export of commodity j;
α_j = proportion of commodity j production costs comprised of imports;
P_{1j} = the appropriate (subsidized) price in local currency; and
$P'_{1j} = P_{wj}R_s$.

Correction for the foreign exchange price divergence proceeds in two steps. First, RP_{wj} must be adjusted for the difference between the SOC of foreign exchange and the official exchange rate, i.e., R_sP_{wj}, since P_{wj} is measured in foreign currency units. Second, the import content of production costs must be raised similarly, i.e., $\alpha_jP_{oj}(R_s/R)$, since P_{oj} is measured in local currency units. Thus, the set of subsidies which will correct for the foreign exchange divergence for commodity j will be

$$(4) \qquad P^*_j = P'_{1j} - P_{oj}(\alpha_j r + 1).^6$$

Note that P^*_j must be calculated separately for each commodity since α_j is specific to the commodity. (For simplicity we drop the subscript j at this point.) Calculation of P^* in this manner implies that production occurs in perfectly competitive conditions and the exporting country has no monopoly power in the world market for the commodities in J. These assumptions are valid for the commodities considered in this paper. Ghana has monopoly power in cocoa exports, her principal source of foreign exchange. The extensions required to analyze this are discussed elsewhere (Blomqvist and Haessel; Haessel and Vickery).

We now turn to a diagramatic representation of the individual terms of equation (4). In figure 1, D represents the short run domestic demand function while S_P and S_s represent, respectively, the private and social short run domestic supply functions for a commodity in the set J. At the existing domestic price, P_o, the quantity OS_o is being produced, Od_o is being consumed, and d_oS_o is being exported. If subsidy P^* raises the price to P_1, production will increase by $\Delta S = S_oS_1$, consumption will decrease by $\Delta D = d_1d_o$, and exports will increase by the sum of the two changes, $\Delta E = \Delta S + \Delta D$.

The marginal social benefit of one unit of export of the commodity is P'_1 regardless of whether a subsidy is being paid. The marginal social cost of production is given by the height of curve S_s. Hence, in the range S_oS_1, the MSB of increased exports exceeds the MSC, and the NSB of expanding output by S_oS_1 and exporting that quantity is given by the area fgh (composed of $fgkt$ of privately and socially perceived benefits offset by $fhkt$ of socially perceived costs). The MSC of decreased domestic consumption is given by the height of the demand curve, which is less than the MSB of increased exports in the range d'_1d_o. Social welfare will be increased if a subsidy of P^* is paid for each unit exported. This will raise the producer price to P_1. The NSB from decreased domestic consumption and increased production would be equivalent to areas $abcd$ and fgh, respectively.

It would not be socially optimal to pay a subsidy equal to $P'_1 - P_o$. While this would reduce domestic consumption to the optimum level of Od'_1 (yielding NSB of ebc), it would at the same time expand production such that MSC > MSB. An excess of social costs equivalent to area fnm will be generated by increasing production from OS_1 to OS'_1. As long as $\partial \text{NSB}/\partial P^* > 0$, it is efficient in social welfare terms to increase the producer price beyond P_1. The optimum subsidy would be attained where $\partial \text{NSB}/\partial P^* = 0$, which will be somewhere between P_1 and P'_1.[7] We limit

[6] This is derived as

$$P^* = P_1 - P_o = R_sP_w - [(1-\alpha)P_o + P_o(R_s/R)] = P'_1 - P_o(\alpha r + 1).$$

[7] At price P_1 there is still an implicit subsidy to con-

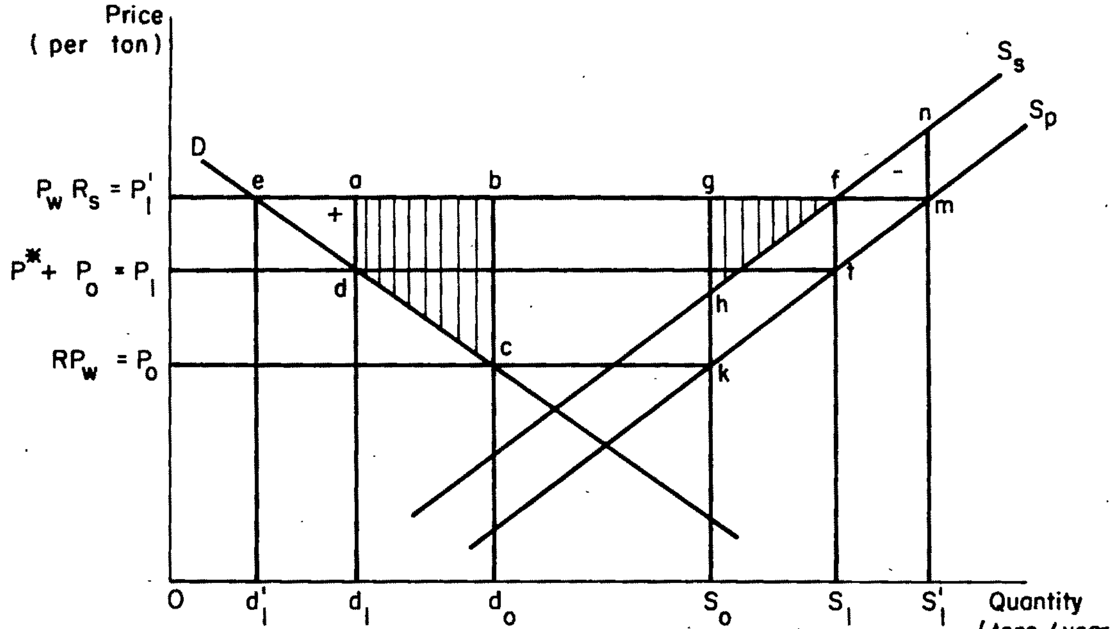

Figure 1. NSB of export subsidies

our analysis to a subsidy set equal to P^* which promises a definite gain in social welfare.

If the demand and supply curves are almost linear over the range of changes in output and consumption and if S_s is parallel to S_P, the gain in social welfare can be approximated as

$$(5)\qquad \Delta W = \frac{1}{2} P^*(\Delta D + \Delta S) + (P'_1 - P_1)\Delta D.$$

We can obtain an empirical estimate of the NSB for each commodity if we know the elasticities of demand and supply and the quantities produced and consumed. If ϵ_S is the elasticity of supply, then

$$(6)\qquad \Delta S = \epsilon_S S_o (P^*/P_o)$$

is an estimate of the supply change. Similarly,

$$(7)\qquad \Delta D = \epsilon_d d_o (P^*/P_o)$$

is an estimate of the change in quantity demanded, where ϵ_d is the absolute value of the demand elasticity.[8]

sumers equal to area $P_1P'_1ed$ in figure 1, the incremental consumer surplus enjoyed by keeping the price at P_1 instead of P'_1. The only way to achieve the economically optimum levels of consumption, production, and exports without a *de facto* devaluation would be with a consumption tax of rP_o and an export subsidy of P^*. The consumption tax would be very difficult if not impossible to administer.

NSB for Subsistence versus Cash Crops

The foregoing discussion is strictly correct only for cash crops, i.e., for those crops grown by the farmer for sale and not consumed on the farm. A qualification is necessary for subsistence crops, i.e., for those crops grown for home consumption as well as for cash sale.

For subsistence crops the farmers' demand curve may shift when the price changes, since the farmers' incomes change (Behrman; Krishna). Thus, the total demand curve for the commodity will also shift. However, the empirical approximation of the NSB of an export subsidy defined by equation (5) is relevant for subsistence crops as well as for cash crops. Figure 2 depicts the case of a subsistence crop. P_o is the producer price prevailing before the subsidy; S_P and S_s represent the private and social short run supply functions; and D_o and D_1 are, respectively, the short run demand functions before and after the subsidy. These demand functions represent the combined demand of both producers and nonproducers. The initial equilibrium is characterized by OS_o being produced, Od_o being con-

[8] Equations (5), (6), and (7) can be used to estimate the NSB of using tariffs to remove the implicit subsidy to consumers from importing commodities with an overvalued exchange rate. See Haessel and Vickery.

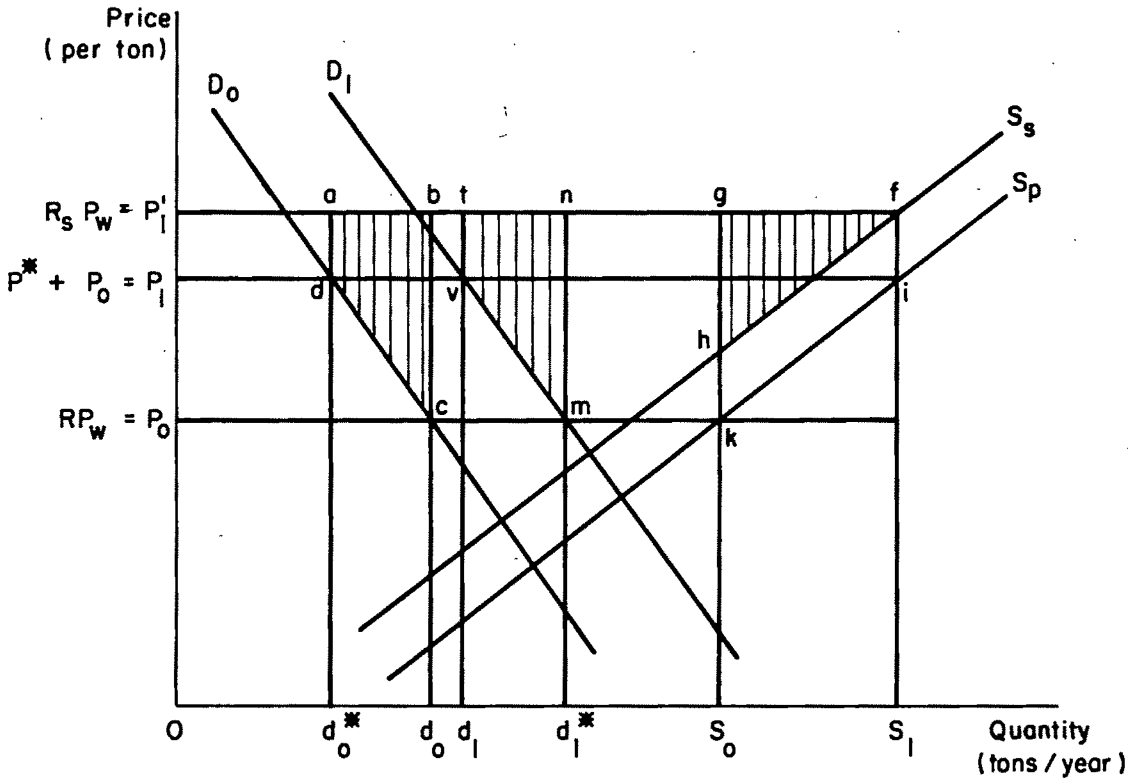

Figure 2. NSB of export subsidies for subsistence crops

sumed, and d_oS_o being exported. When the export subsidy of P^* is introduced, the producers' surplus increases by the area P_1P_oki. This increase in their money (and real) income shifts the total domestic demand curve to D_1. The new equilibrium with the subsidy is where OS_1 is produced, Od_1 is consumed, and d_1S_1 is exported. This means less exports than the situation described for cash crops, which would be $d^*_oS_1$.

Suppose, however, that the producer price subsidy is combined with a lump-sum tax on the producers so that their money incomes with the subsidy plus tax are equal to their incomes without subsidy or tax (i.e., the tax would be equal to the area P_1P_oki).[9] Then domestic consumption with the subsidy would be Od^*_o and quantity d^*S_1 would be exported. The NSB of a policy of subsidy-cum-lump-sum-tax would be equal to the areas *abcd* plus *fgh* and could be approximated using equation (5). The lump-sum tax is simply an income redistribution device which does not affect the NSB to the economy as a whole. That the producers choose to consume more of the subsidized commodity without the lump-sum tax does not diminish the NSB.[10]

EMPIRICAL RESULTS FOR GHANA

Cocoa earnings, including beans and cocoa products, have typically constituted about two-thirds of Ghana's total export earnings throughout the years 1955–71.[11] Ghana's share of world cocoa production has fluctuated between 25% and 40% since 1960, which suggests that she has some monopoly power in the world market. Blomqvist and Haessel estimated that the 1971 producer price was about optimum to equate MSR and MSC. Thus, there was little scope for improvement from cocoa, and we concentrate on estimating increases in NSB which can be

[9] The result is a demand curve for a constant money income, which is one of the items usually included in the *ceteris paribus* assumptions. See Friedman.

[10] Alternatively, starting from a situation with a subsidy but without a lump-sum tax, consumption would be Od_1 and exports d_1S_1. If the export subsidy is removed and the producers are given a lump-sum transfer equal to area P_1P_oki, the demand curve would remain unchanged and d^*_1 would be consumed. Exports would be reduced to $Od^*_1S_o$, and the cost to the economy would be equal to areas *tnmv* plus *fgh*. The sum of these two areas can be approximated by equation (5).

[11] See Stern (p. 52).

achieved via export subsidies on other tradeable agricultural commodities.

Table 1 summarizes our estimates of NSBs in 1971 for selected crops from setting producer prices equal to P_1, the social value of output.[12] Three categories of crops are distinguished: tree crops, starchy foods, and other cash crops.

Tree crops are characterized by relatively small absolute levels of output (compared to the subsistence crops of yam, for example). Further, tree crops display highly inelastic short run supply functions. Coffee is further complicated by export quotas imposed by the International Coffee Agreement. Since Ghana filled her entire quota in 1971, the NSBs for coffee were evaluated at 1971 nonquota prices. In spite of this, the NSBs of expanded coffee exports are quite large.[13]

Since total Ghanaian output of other cash crops is insignificant relative to total world demand, increased exports will have a negligible effect on world prices. Also, output for these crops can be expanded with a lag of less than eighteen months. This combination of favorable characteristics suggests that export subsidies on other cash crops possess great potential for generating NSB. The large NSB estimated in table 1 for groundnuts and pineapples is consistent with this hypothesis.[14]

Starchy foods generally appear to have low export potential.[15] The message of table 1 is that maize and bananas should not be traded, and that rice and guinea corn (sorghum) are produced more efficiently in other countries. In fact, increased imports of guinea corn would have generated positive NSB. Imported rice is somewhat underpriced and a tariff increase will yield a positive NSB. Other potentially exportable starchy foods are cocoyam, yam, and plantain. However, total world imports of these crops are small and increased exports could probably not be marketed without substantial declines in world prices.

To summarize, table 1 reports estimates of the NSB to be gained by instituting an appropriate system of export subsidies, import tariffs, and increasing imports of guinea corn to supplement domestic production. Of the commodities considered, coffee, cola nuts, groundnuts, and pineapples are the best prospects for additional exports. Of the starchy foods, none have any export potential, but rice imports should be reduced. The status quo in maize and guinea corn is about correct, and bananas should not be traded. Based on the assumed responsiveness of producers and consumers, total NSB of the subsidies program is estimated between 5.2 and 8.7 million cedis for the commodities considered. (According to the 1971 official exchange rate, ¢1.02 = \$1.00.)

FINANCING THE SUBSIDIES

One of the more serious disadvantages of a system of export subsidies is the fiscal burden it places on the government budget. The cost of an optimal export-bonus/import-tariff scheme would be given by

$$(8) \qquad \Delta G = \sum_i E_i P^*_i - \sum_j M_j T^*_j,$$

where i and j are summed over all the exports and imports involved in the scheme. Using equation (8) to evaluate the implications for the government budget for the ten commodities considered, we find net expenditures of ¢6.5 and ¢11.3 million would be required to finance the scheme for the low and high estimates respectively. These estimates range from 1.9% to 3.3% of the Ghanaian government's recurrent expenditures for the fiscal year 1970–71.[16] Our analysis included only a few of the potential exports, but it is clear that an export bonus scheme of this type can place a tremendous burden on the government budget.

If, as a result of the increased foreign exchange earnings, imports increase by ΔM, the scheme will be at least partly self-financing. Government revenue collected as tariffs on all imports M will be sufficient to finance the export bonus scheme if $T^w M > EP^w$, where T^w and P^w are weighted average tariff and subsidy rates and M and E are total imports and exports. Unfortunately, some of the tariff revenue collected

[12] The basis for selecting the commodities which appear in table 1 was data availability. Consequently, the estimated NSB reported in this table is not intended to represent the NSB for all of Ghanaian agriculture. Rather, they should be viewed as illustrative of the order of magnitude.

[13] Other promising tree crops, for which insufficient data are available, include significant quantities of lime juice, which Ghana exports, as well as avocados, grapefruits, lemons, mangoes, and oil seeds, which are produced in large quantities for local consumption.

[14] Other promising commodities in this class include peppers and onions.

[15] An exception may be cassava chips used for animal feed.

[16] Mensah reports recurrent expenditure at ¢345.7 million.

Table 1. NSB from Establishing Optimum Export Subsidies and Import Tariffs for Selected Agricultural Commodities in Ghana: 1971

	Tree Crops				Starchy Foods				Other Cash Crops		
	Coffee	Cola Nuts	Copra	Oranges	Bananas	Guinea Corn	Maize	Rice	Ground-nuts	Pine-apples	Total NSB
1971 Quantities, '000 long-tons											
Total production, S_o	33[a]	23[b]	25[c]	74[d]	16[a]	170[e]	378[e]	54[e]	100[e]	25[e]	
Exports or (Imports), d_oS_o	5[f]	2[f]	—	—	—	—	(3)[f]	(35)[f]	—	—	
Domestic consumption, d_o	28	21	25	74	16	170	381	89	100	25	
Demand elasticities,[g] ϵ_d											
Low	−0.20	−0.18	−0.10	−0.32	−0.32	−0.79	−0.79	−0.52	−0.59	−0.32	
High	−0.29	−0.27	−0.20	−0.50	−0.50	−1.97[x]	−1.97[x]	−1.36[x]	−0.84	−0.50	
Supply elasticities,[h] ϵ_s											
Low	0.16	0.16	0.05	0.05	0.10	0.14	0.14	0.20	0.50	0.10	
High	0.40	0.50	0.10	0.10	0.20	0.18	0.18	0.46	0.70	0.20	
1971 Market prices, ¢/long-ton											
Export price FOB tema, $P_{w}R$	360[n]	191[f]	68[l]	163[i]	40[l]	(110)[y]	(70)[f]	(173)[f]	243[i]	85[i]	
Tema wholesale price P_o	349[j]	191[k]	185[j]	92[m]	66[m]	162[y]	118[n]	218[n]	282[m]	64[m]	
Proportion of P_o represented by foreign exchange, α	0.13[j]	0.17[p]	0.07[j]	0.19[j]	0.10[p]	0.23[q]	0.23[q]	0.38[q]	0.17[p]	0.24[p]	
1971 Social prices, ¢/long-ton[r]											
Export value FOB Tema, P'_1	618	328	280	117	69	157[l]	120	299	417	146	
Optimum producer price Tema, P_1	586	305	271	104	64	157[v]	119	240	383	135	
Optimum change price (P* for exports)	237	114	86	12	−2	(−5)[v]	(1)	(22)	101	71	
Optimum tariff $T^* = P_1 - P_w R$						47	50	67			
Rate of subsidy (tax), P^*/P_o	0.68	0.60	0.46	0.13	−0.03	(−0.03)	(0.01)	(0.10)	0.36	1.11	
ΔExports (ΔImports), ('000 long-tons)[s]											
Low	7	5	2	3	—	(5)	(−3)	(−6)	39	12	
High	14	10	3	6	—	(11)	(−3)	(−14)	55	20	
NSB, '000 ¢/year[t]											
Low	1,157	308	95	57	—	32[w]	1[w]	361	2,664	531	5,206
High	2,124	718	147	101	—	63[w]	1[w]	878	3,770	874	8,676

[a] Derived from Ghana (1971a). Production for 1971 was assumed equal to 1970.
[b] Rough estimates based on area under cola (Ghana 1971c, Vol. I, p. 73).
[c] Rough estimate of copra-equivalent. Total output of coconuts in 1970 from Ghana (1971a). This was converted to copra at a ratio of 1:8 (Dalton and Famiyeh).
[d] The figure is 5% higher than the 1970 figure, since total production during 1966–70 increased by an average of 5% per year.
[e] From Ghana (1971c, Vol. II, p. 26).
[f] Derived from Ghana (1962–71a). The prices for maize and rice are import prices.
[g] Unless otherwise noted, demand elasticities are from Bussink (pp. 208–11).
[h] Supply elasticities come from a variety of sources. Estimates of coffee and cola nuts are based on coffee and cocoa supply elasticities reported by Bateman (p. 251) for Ghana, Colombia, and Brazil. No estimates were available for copra, oranges, bananas, and pineapples, so arbitrarily low elasticities were selected. Guinea corn, rice, and maize elasticities are based on estimates reported by Krishna (pp. 506–7) for India, Pakistan, Indonesia, and the Philippines. The estimates for groundnuts are based on Parikh for India.
[i] Derived from Great Britain; United Nations, FAO; Societe Rene Moreux et Cie. Averaging c.i.f. prices at European ports for the three months following the three peak Ghanaian harvest months for each crop and deducting ocean freight (based on Conference rates) yields estimated export prices f.o.b. Tema (Ghana) in foreign currency. These were converted to cedis at the 1971 official exchange rates.
[j] Derived from Dalton and Famiyeh and adjusted for transport and packaging costs to Tema.
[k] Domestic cost f.o.b. Tema is assumed to equal the 1971 average export price.
[l] Calculated by shadow pricing imports differently from transport which has a domestic component.
[m] Based on average harvest-time wholesale prices (three lowest months) in Accra (Tema) during 1971, as reported in Ghana (1971b). These prices were increased by 10% to cover packaging costs for export (based on advice from Black Star Lines).
[n] Based on Ghana (1971b). No adjustment for export packaging costs was required since domestic production is being compared to the alternative of imports.
[o] Price that would prevail without imports.
[p] Based on Kuranchie. The foreign exchange component for groundnuts was used for cola nuts, yams for bananas, and tomatoes for pineapples.
[q] Taken from Gilbert (tables 3a and 3b). Estimates for maize are assumed to apply to guinea corn also.
[r] See Section I.B. for definitions. R_s was estimated to be ¢1.75/U.S.$ (see Roemer and Stern, chap. 3), while the official exchange rate was ¢1.02/U.S.$.
[s] Calculated as the sum of equations (6) and (7). For subsistence crops, this is a misnomer.
[t] Calculated using equation (5).
[u] From Ghana (1962–71a). This is the average value of exports to China who is not a member of the International Coffee Agreement (ICA). Since Ghana sold her entire ICA quota allotment in 1971, additional sales would have to be made at below average prices to nonmember countries.
[v] Since $P_o > P_w R_s - \alpha r$, the optimum producer price is $P_w R_s$ and $P^* = P_o - R_w R_s$.
[w] Calculated as $\frac{1}{2}(\Delta S + \Delta D)\ P^* + \alpha r P_o \Delta S$ in the case of increased imports.
[x] From Haessel.
[y] These prices are for Tamale (Northern Region). The import price is from Ghana (1962–71a) and includes transport costs to Tamale. The value for P_o is from Ghana (1971b). Tamale is used as a base point because most guinea corn is grown and consumed in Northern Ghana and transport costs between Tema and the north are significant. The domestic price (P_o) at Tema was ¢196 and the social import price was ¢112 per long ton. This would suggest that substantial imports would be desirable.

prior to the export bonus scheme will be earmarked for other uses, and only some portion of ΔMT^{w} will be available for financing the export bonus scheme.

This portion will be insufficient to finance the increased expenditure required. For the ten commodities considered in table 1, the additional net foreign exchange earnings are ¢17.6 and ¢26.4 million for the low and high estimates respectively. Historically, the weighted average import tariff rate for Ghana, T^{w}, has varied between 15% and 30%.[17] Assuming that all the additional net foreign exchange earnings are spent on imports, we get the results in table 2 for three alternative assumptions about T^{w}. Depending on the tariff rate and the responsiveness of the producers and consumers, the subsidy scheme may be anywhere from 33% to 68% self-financing. When this self-financing aspect is taken into account, the net increase in government expenditure (deficit) implied by the scheme varies from between 0.6% and 2.3% of the 1970–71 recurrent government budget.

SUMMARY AND CONCLUSIONS

We have developed a methodology for evaluating the NSB of instituting a system of optimal export subsidies and import tariffs. We have also discussed a technique for evaluating consumer surplus when the demand curve shifts due to an income change. In applying this method to selected Ghanaian data to estimate the social profitability of an export subsidies scheme, we found that such a policy would have yielded substantial social benefits given the private and social prices prevailing in 1971. While such a program requires large government expenditures, if increased foreign exchange earnings are matched by increased imports, the program would be anywhere from 33% to 68% self-financing, thus substantially reducing the burden on the government budget.

If the system of optimal export subsidies and import tariffs is extended to cover all traded commodities, the economy will in fact have experienced a *de facto* devaluation as far as incentives to importers and exporters are concerned.[18] However, a *de jure* devaluation has two major advantages over a *de facto* devaluation. A *de jure* devaluation avoids the fiscal burden discussed above[19] and is much easier to administer than a system of export subsidies and import tariffs. Given that highly qualified administrative personnel tend to be scarce in less developed countries, this is an important consideration. Unfortunately, all too often devaluation is considered to be a politically unacceptable policy. In the event that the problem of an overvalued exchange rate is impossible to solve through devaluation, we recommend a policy of export subsidies. That, however, is our second choice.

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17 This is based on the cedi value of total imports (Ghana 1962–71a) and the cedi value of import tariffs collected (Ghana 1962–71b).

18 Applying our methodology to all tradeable commodities in the economy would amount to evaluating the NSB of a devaluation.

19 Teigeiro and Elson found that even though the various export schemes used in Colombia were very effective in stimulating exports, the fiscal burden was substantial enough that they recommended greated reliance on exchange rate adjustments as an export promotion device.

Table 2 Fiscal Implications of the Export Subsidies

	T^{w}	Increases in Tariff Revenue[a] Millions	Percent Self-Financing[b]	Deficit[c] Millions	Deficit as Percent of Recurrent Budget[d]
Low estimates	15%	2.2	34	4.3	1.2
$\Delta G =$ ¢6.5 M	22%	3.2	50	3.3	1.0
$\Delta Fx =$ ¢14.6 M	30%	4.4	68	2.1	0.6
High estimates	15%	3.7	33	7.6	2.3
$\Delta G =$ ¢11.3 M	22%	5.5	49	5.8	1.7
$\Delta Fx =$ ¢24.8 M	30%	7.4	66	3.9	1.1

[a] Calculated as $\Delta T = \Delta FX.T^{w}/100$.
[b] Calculated as $100\Delta T/\Delta G$.
[c] $\Delta G - \Delta T$.
[d] Calculated as $100(\Delta G - \Delta T)/G$, where G = ¢345.7*M*. is the recurrent government expenditure in Ghana in the 1970–71 financial year as reported by Mensah. This figure does not include debt servicing.

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IMPROVING ESTIMATES OF ECONOMIC PARAMETERS BY USE OF RIDGE REGRESSION WITH PRODUCTION FUNCTION APPLICATIONS

WILLIAM G. BROWN and BRUCE R. BEATTIE

Ridge regression is a promising alternative to deletion of relevant variables for alleviating multicollinearity and can provide smaller mean square error estimates than unbiased methods such as OLS. However, ridge estimates can also be unreliable and misleading under certain conditions. To avoid erroneous conclusions from ridge regression, some prior knowledge about the true regression coefficients is helpful. A theorem on expected bias implies that ridge regression will give much better results for some economic models, such as certain production functions, than for others because of smaller expected bias.

Key words: economic model estimation, multicollinearity, ridge regression.

Much of the evolution and development of estimating procedures in econometrics has been motivated by a desire to reduce the bias which may result from the use of ordinary least squares (OLS) estimating procedures. Therefore, to suggest the deliberate use of some biased estimating procedure in order to improve the accuracy of economic parameter estimation may appear almost blasphemous. Nevertheless, if the mean square error (MSE) criterion is used as a measure of accuracy, there always exists a more accurate "ridge regression" estimate than the unbiased OLS estimate, as shown by Hoerl and Kennard (1970a, pp. 61–63) or a more accurate "shrunken" estimate as shown by Mayer and Willke (pp. 503–4), even though these last two estimators are biased.[1]

In practice, serious difficulty with OLS or other unbiased estimating methods, such as generalized least squares, may arise because of problems of multicollinearity. High correlation among explanatory variables in economic models sometimes occurs because of the highly aggregated or grouped nature of economic data. The underlying logic for increased correlation between grouped or aggregated variables was shown in 1964 by Cramer, but the important implications of increased correlation of grouped variables for economic models involving many explanatory variables seems to have been overlooked until recently noted (Brown and Nawas 1972; Brown and Nawas 1973). Economists also encounter multicollinearity because many economic variables tend to move up and down together over time, and/or because the number of nonorthogonal explanatory variables is relatively large compared to the number of observations.

At any rate, given problems of multicollinearity, what should be done? In some cases, the original individual observations can be used to reduce intercorrelation and give more precise estimates. However, this procedure is often impossible when working with secondary data, such as census data, where the anonymity of the respondents is protected.

The resolution of this dilemma has often been to automatically delete variables from the original formulation of the model. Unfortunately, this "solution" can have a high cost, omitted-variable-specification-bias, as shown by Theil (1957), the large potential magnitude of which has been demonstrated by Brown. Obviously, alternative procedures are needed for coping with the multicollinearity problem. Admittedly, variable deletion has not yet been proved generally

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[1] By definition, the MSE of an estimated parameter, $\hat{\theta}$, is $E(\hat{\theta} - \theta)^2$, which implies MSE $(\hat{\theta})$ = variance $(\hat{\theta})$ + square of bias $(\hat{\theta})$.

inferior to other methods for ameliorating multicollinearity. Also, progress has been made in selection of subset-regression models (Mallows), although additional research is needed (Hocking).

Various methods for incorporating prior information into regression analysis can be used to ameliorate the difficulties of multicollinearity.[2] Even a subjective probability estimate for given parameter(s) can often be used to reduce multicollinearity (Theil 1963; Theil 1961). Similarly, prior knowledge about the permissible bounds for a coefficient (e.g., that a probability must take a value, $0 \leq p_i \leq 1$) can be used to form inequality constraints which can significantly lessen difficulties of multicollinearity (Judge and Takayama).

Another promising approach for the estimation of models with multicollinearity is through the use of so-called "ridge regression," which is, in effect, another way of incorporating prior information into the estimating procedure (Hoerl and Kennard 1970a, p. 64). Potential gains from and limitations of the use of ridge regression for estimation of economic models are explored analytically and by means of some simple Monte Carlo experiments in this paper. In the final section, ridge procedures are applied in estimating the marginal value productivity of irrigation water.

DEFINITION AND VARIANCE OF THE RIDGE REGRESSION ESTIMATOR

The basic idea of ridge regression is quite simple. Multicollinearity is mitigated by augmenting the main diagonal elements of the correlation matrix by small positive quantities. Following Hoerl and Kennard (1970a), let $X'X$ represent the correlation matrix of explanatory variables. Then assume the linear model

$$(1) \qquad Y = X\beta + u,$$

where Y is $n \times 1$, fixed X is $n \times p$, β is $p \times 1$, u is $n \times 1$, $Eu = 0$, and $Euu' = \sigma^2 I$. The ridge estimator, $\hat{\beta}^*$, is defined as

$$(2) \qquad \hat{\beta}^* = (X'X + kI)^{-1} X'Y,$$

where k denotes a small positive increment. We can assign k increasing values, such as $k = 0.1$, 0.2, 0.3, . . . , and the k value can be selected where the ridge estimates "stabilize," according to the Ridge Trace (Hoerl and Kennard 1970b). ("Ridge Trace" denotes a simple graph of the values of the ridge estimates on the vertical axis plotted against the corresponding values of k on the horizontal axis.)

From equation (2), the ridge estimate can be written as

$$(3) \qquad \hat{\beta}^* = \beta + \gamma + (X'X + kI)^{-1} X'u$$

by substituting for Y from equation (1) where γ represents the bias in $\hat{\beta}^*$. By definition (Johnston, p. 125), the variance-covariance matrix for $\hat{\beta}^*$ is

$$\begin{aligned}(4) \quad \text{var-cov}(\hat{\beta}^*) &= E[(\hat{\beta}^* - E\hat{\beta}^*)(\hat{\beta}^* - E\hat{\beta}^*)'] \\ &= E\{[(X'X + kI)^{-1} X'u][(X'X + kI)^{-1} X'u]'\} \\ &= \sigma^2 (X'X + kI)^{-1} X'X (X'X + kI)^{-1}.\end{aligned}$$

For the experiments presented later, it was much easier to interpret and summarize the results by working with the mean-corrected sums of squares and cross-products rather than the correlations. In terms of the corrected sums of squares and cross-products, the nonstandardized ridge regression coefficient vector is

$$(5) \qquad \hat{\beta}^* = (X'X + k\lambda)^{-1} X'Y,$$

where $X'X$ represents the $p \times p$ matrix of mean-corrected sums of squares and cross-products, and λ is a diagonal matrix of order p consisting of the sums of squares. Then, the equivalent of equation (4) for the regular (nonstandardized) ridge regression coefficients is

$$\begin{aligned}(6) \quad &\text{var-cov}(\hat{\beta}^*) \\ &= \sigma^2 (X'X + k\lambda)^{-1} X'X (X'X + k\lambda)^{-1}.\end{aligned}$$

The variances as defined by equation (6) are appropriate for the simple experiments to be reported here in terms of the regular ridge regression coefficients. However, before the experimental results can be properly interpreted, the expected bias of the ridge estimator should be reviewed, since the reduced variance in equations (4) or (6) as k increases could be more than offset by bias, which increases as k increases (Hoerl and Kennard 1970a).

[2] Farrar and Glauber suggest an analysis to detect those explanatory variables most affected by multicollinearity by computing the r^{ii}, which correspond to the main diagonal elements of the inverted correlation matrix of the explanatory variables. Inspection of the r^{ii} will indicate how much the variance of each coefficient is being inflated by multicollinearity. Hence, the r^{ii} have been termed "variance inflation factors."

EXPECTED BIAS OF THE RIDGE REGRESSION ESTIMATOR IN TERMS OF THE TRUE β VALUES

Although Hoerl and Kennard (1970a, p. 60) derive the proper expression for the bias squared of the standardized ridge estimator in terms of k and the true standardized β values, the extreme impact of the true β values and the relationship among the explanatory variables upon the expected bias in ridge regression has not been noted. This important effect on the bias will be illustrated by sampling experiments. First, however, an elementary derivation in terms of nonstandardized β values is presented.[3] By assuming fixed X values in equation (5), substituting $X\beta + u$ for Y, and taking expected values, we obtain

$$
\begin{aligned}
(7)\quad E\hat{\beta}^* &= (X'X + k\lambda)^{-1}(X'X)\beta \\
&= (X'X + k\lambda)^{-1}(X'X + k\lambda - k\lambda)\beta \quad \text{since } Eu_i = 0 \\
&= (X'X + k\lambda)^{-1}(X'X + k\lambda)\beta - (X'X + k\lambda)^{-1}(k\lambda)\beta \\
&= \beta - k(X'X + k\lambda)^{-1}\lambda\beta.
\end{aligned}
$$

Letting $A^* = (X'X + k\lambda)$,

$$(8)\quad E(\hat{\beta}^*) - \beta = \frac{-k}{|A^*|}(\operatorname{adj} A^*)\lambda\beta.$$

Of course, for standardized variables, $X_i'X_i = 1$ for all i; thus, $\lambda = I$, and can be ignored in equation (8). The significance of equation (8) can be more easily seen for the simple case of two standardized explanatory variables. Then, for $\hat{\beta}_1^*$, equation (8) implies that

$$(9)\quad E(\hat{\beta}_1^*) - \beta_1 = \frac{-k}{(1+k)^2 - r_{12}^2}[(1+k)\beta_1 - r_{12}\beta_2],$$

where r_{12} denotes the correlation between the two explanatory variables, X_1 and X_2, and k denotes the amount of increment of the main diagonal elements of the correlation matrix.

Note that in equation (9), for the usual case of high positive correlation between economic variables, the expected bias in $\hat{\beta}_1^*$ will be lessened if the true β values have the same sign, and even more so if they are also of about equal magnitude. Conversely, if β_1 and β_2 are of opposite signs (and X_1 and X_2 are positively correlated), then the expected bias in $\hat{\beta}_1^*$ will be greatly increased, as indicated by equation (9). (Of course, if r_{12} in equation (9) were negative, then bias squared and MSE will be smallest when β_1 and β_2 are about equal in absolute magnitude but differ in sign.)

The implication of equation (9) for the two-explanatory-variables model can be generalized to the case of p standardized explanatory variables by means of an original theorem which is proved in the appendix.[4] According to this theorem, the expected bias for the ridge estimate of the coefficient of the jth variable in the model $Y = X\beta + u$ is

$$(10)\quad E(\hat{\beta}_j^*) - \beta_j = \frac{k\,c_{jj}}{|A^*|}[\hat{b}_{j1}^*\beta_1 + \hat{b}_{j2}^*\beta_2 + \ldots + \hat{b}_{j,j-1}^*\beta_{j-1} - 1.0\,\beta_j + \hat{b}_{j,j+1}^*\beta_{j+1} + \ldots + \hat{b}_{jp}^*\beta_p].$$

In equation (10), $\hat{b}_{ji}^*$ denotes the ridge estimate of the coefficient for the ith variable, where X_j has been regressed on the $p - 1$ remaining explanatory variables, where $A^* = (X'X + kI)$, and where c_{jj} is a cofactor of A^*. From the theorem and from the fact that the sum of the $\hat{b}_{ji}^*$ values will usually be nearly 1.0 for economic models with positive intercorrelation (as illustrated in appendix table 1), it follows that the bias and MSE for the ridge estimate of the jth coefficient will be relatively small if the true β values all have the same sign and β_j is approximately equal to the average of the other $p - 1$ β values. Thus, some economic models, such as production functions, may be very well suited for estimation by means of ridge regression. On the other hand, ridge estimation of other economic models, such as certain demand functions, could give very poor or misleading results. The crucial importance of similar sign and magnitude of the standardized regression coefficients for models with positively correlated explanatory variables is illustrated by the simple experiments of the next section.

[3] The ith observation of the standardized variable, X, is defined as:

$$X_i = \frac{X_i - \overline{X}}{\sqrt{\Sigma x_i^2}}.$$

[4] The authors are indebted to T. D. Wallace for suggesting a more clear and elegant approach for deriving this theorem than the tedious proof first used by Brown (pp. 31–32).

EXPERIMENTAL RESULTS FOR TWO-EXPLANATORY-VARIABLE MODELS

The surprising estimating power of ridge regression for nonorthogonal data can be shown by experimental results from the simple two-explanatory-variable model,

$$(11) \qquad Y_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + u_t,$$

where $E(u_t) = 0.5(4) + 0.5(-4)$ and $E(u_t u_{t+s}) = 0$ for all $s \neq 0$. The five fixed values for X_{1t} and X_{2t} were, respectively, (1,1.2), (2,1.67335), (3,3), (4,4.32665), and (5,4.8). By taking all possible samples ($2^5 = 32$) generated by the simple binomial error term, the distribution of the OLS estimates of β_1 and β_2 were computed and results summarized for various values of β_1 and β_2.[5] Although the binomial error term in combination with five observations gives only nine different values of $\hat{\beta}_1^*$ and $\hat{\beta}_2^*$, the expected MSE for $\hat{\beta}_1^*$ and $\hat{\beta}_2^*$ would be the same for any distribution, since the variance and bias of ridge estimates do not depend upon how the error term is distributed, as can be seen from equations (6) and (7).

Values were assigned to β_1 and β_2 so that $R^2 \doteq 0.9085$ was maintained for each regression model to cover both "good" and "bad" situations for the use of ridge regression, as implied by equations (9) and (10). The various assigned β values were the following:

model number	β_1 value	β_2 value
1	4.0000	4.0000
2	5.3300	2.6650
3	7.9706	0.0000
4	9.9180	−1.9836
5	15.4932	−7.7466.

The OLS estimates in table 1 for model 1 are quite variable, ranging from −10.657 to 18.657 for the estimates of β_1 and with a similar range for the estimates of β_2. Although the true value of $\beta_1 = 4$ is obtained by OLS 4/16 of the time, 5/16 of the time the proper sign for $\hat{\beta}_1$ is not obtained. Similarly, the true value of $\beta_2 = 4$ is also obtained 4/16 of the time by OLS, but negative values occur 6/16 of the time. This erratic behavior of the OLS estimated coefficients is reflected in the high variances for $\hat{\beta}_1$ and $\hat{\beta}_2$ in the lower part of table 1. Since the OLS estimates are unbiased, the MSE in the last two lines of table 1 is equal to the variance for OLS.

The main reason for the large variances of the OLS estimates in table 1 is, of course, the high intercorrelation between X_1 and X_2, $r_{12} = 0.985$. If X_1 and X_2 were orthogonal, the variance of $\hat{\beta}_1$ would be $\sigma^2 \div \Sigma x_{1t}^2 = 16/10$. Since X_1 and X_2 are correlated, the variance inflation factor is $1/(1 - r_{12}^2) \doteq 34.3$. Thus, the variances of $\hat{\beta}_1$ and $\hat{\beta}_2$ are increased by this amount because of multicollinearity.

Ridge regression estimates in table 1 show a dramatic reduction in variability compared to OLS. For $k = 0.1$, the variance of $\hat{\beta}_1^*$ is 1.258, only slightly over 2% of that for $\hat{\beta}_1$; the variance of $\hat{\beta}_2^*$ is similarly reduced. However, more important than the size of the variance itself is the dramatic reduction in the MSE for $\hat{\beta}_1^*$ and and $\hat{\beta}_2^*$. For $k = 0.25$, MSE for $\hat{\beta}_1^*$ and $\hat{\beta}_2^*$ is less than 1.25% that for OLS. Such great improvement in accuracy of estimation from ridge regression in table 1 makes one wonder if OLS regression is not obsolete for most economic research with nonorthogonal data. However, recall from the earlier discussion of equations (9) and (10) that for high positive correlation between two explanatory variables, bias is increased if the true β values are of unequal magnitude or of different sign.

Results averaged across all experiments are shown for models 2, 3, 4, and 5 in table 2. As could be predicted from equations (9) and (10), the relative advantage of ridge estimation over OLS declines as the difference in magnitude, $\beta_1 - \beta_2$, increases from model 2 to model 5. For model 2, the sum of MSE $(\hat{\beta}_1^*)$ + MSE $(\hat{\beta}_2^*) =$ 4.525 for $k = 0.20$, only about 4.12% of that for OLS. Although MSE was greatly reduced by ridge regression for model 2, some bias was encountered. For example, for $k = 0.20$, an expected value of $\hat{\beta}_1^* = 3.723$ implies a bias of $(3.723 - 5.33)/5.33 \doteq 30\%$. For $\hat{\beta}_2^*$ and $k =$ 0.20, the percentage bias was even worse, equal to over 32% of the true β_2 value of 2.665. Thus, even with substantial reduction in MSE, as for model 2, bias can become relatively large.

Substantial bias possible from ridge regression is illustrated even more strongly by results from

[5] It should be noted that the estimates of α are not included in table 1. The ridge estimates of β_1 and β_2 were obtained by solving the normal equations in terms of the mean-corrected sums of squares and cross-products, as indicated by equation (5). Although apparently not discussed in the literature, one could define $\alpha^* = \bar{Y} - \hat{\beta}_1^* \bar{X}_1 - \hat{\beta}_2^* \bar{X}_2$. Then, one can derive the variance of α^* in terms of the variances and covariance of $\hat{\beta}_1^*$ and $\hat{\beta}_2^*$ (Brown, p. 20).

Table 1. Distribution of Estimated β_1 and β_2 Coefficients for OLS versus Ridge Regression, Model 1, where $Y_i = \alpha + 4X_{1i} + 4X_{2i} + u_i$, $E(u_i) = 0.5(4) + 0.5(-4)$, and Fixed X_1 and X_2 Take the 5 Values (1,1.2), (2,1.67335), (3,3), (4,4.32665), and (5,4.8)

		Distribution of $\hat{\beta}^*_1$ and $\hat{\beta}^*_2$ for Several Levels of k						
Probability	Variable Number	$k = 0$ (OLS)	$k = 0.05$	$k = 0.10$	$k = 0.15$	$k = 0.20$	$k = 0.25$	$k = 0.30$
1/16	1	−10.657	0.355	1.688	2.164	2.383	2.493	2.548
	2	18.063	6.870	5.363	4.722	4.346	4.085	3.886
2/16	1	− 4.438	2.339	3.115	3.361	3.451	3.475	3.467
	2	13.375	6.379	5.394	4.948	4.668	4.463	4.297
2/16	1	− 2.219	1.918	2.382	2.521	2.566	2.570	2.556
	2	8.688	4.392	3.777	3.493	3.311	3.175	3.064
1/16	1	1.781	4.322	4.542	4.559	4.519	4.458	4.386
	2	8.688	5.889	5.425	5.174	4.991	4.840	4.708
4/16	1	4.000	3.902	3.808	3.719	3.634	3.553	3.475
	2	4.000	3.902	3.808	3.719	3.634	3.553	3.475
1/16	1	6.219	3.481	3.075	2.879	2.748	2.648	2.564
	2	− 0.688	1.914	2.191	2.264	2.277	2.265	2.242
2/16	1	10.219	5.886	5.235	4.917	4.702	4.535	4.394
	2	− 0.688	3.411	3.839	3.945	3.957	3.930	3.886
2/16	1	12.438	5.465	4.501	4.077	3.817	3.630	3.483
	2	− 5.375	1.424	2.222	2.490	2.599	2.643	2.652
1/16	1	18.657	7.449	5.928	5.274	4.885	4.612	4.403
	2	−10.063	0.937	2.254	2.716	2.922	3.020	3.063
$E(\hat{\beta}^*_1)$		4.000	3.902	3.808	3.719	3.634	3.553	3.475
$E(\hat{\beta}^*_2)$		4.000	3.902	3.808	3.719	3.634	3.553	3.475
$E\,\mathrm{var}(\hat{\beta}^*_1)$		54.936	3.190	1.258	0.781	0.587	0.485	0.423
$E\,\mathrm{var}(\hat{\beta}^*_2)$		54.936	3.190	1.258	0.781	0.587	0.485	0.423
$E\,\mathrm{MSE}(\hat{\beta}^*_1)$		54.936	3.199	1.295	0.860	0.721	0.686	0.698
$E\,\mathrm{MSE}(\hat{\beta}^*_2)$		54.936	3.199	1.295	0.860	0.721	0.686	0.698

model 3 in table 2. Model 3 illustrates the danger of being misled by ridge regression if one does not have prior information regarding the true β values. Suppose, for example, that the expected MSE was thought to be only 0.721 at $k = 0.20$, similar to model 1 in table 1. Then, one might ignore the bias and think that β_2 was significantly different from zero, since $\hat{\beta}^*_2$ averages 3.348 for $k = 0.20$. The individual estimates of $\hat{\beta}^*_2$ for each experiment are not shown in table 2, but varied from 1.991 to 4.706 for $k = 0.2$ (Brown, p. 24). The ratio of $\hat{\beta}^*_2$ to the square root of its variance at $k = 0.2$ ranged from 2.55 to 9.71 (Brown, p. 23).

Ridge regression results continued to worsen with model 4, as would be predicted from equations (9) and (10). Although not shown in table 2, the smallest sum of MSE for $\hat{\beta}^*_1$ and $\hat{\beta}^*_2$ was observed at $k \doteq 0.02$, where MSE $(\hat{\beta}^*_1)$ + MSE $(\hat{\beta}^*_2) \doteq 43.89$. Expected values at $k = 0.02$ were $E(\hat{\beta}^*_1) = 6.446$ and $E(\hat{\beta}^*_2) = 1.410$. Thus, a substantial bias was encountered, the relative bias of $\hat{\beta}^*_1$ being about 35% and the relative bias for $\hat{\beta}^*_2$ being about 171% of the true value. (The MSE function for the ridge estimator will always have an unique minimum for some $k > 0$, due to the properties of the variance and squared bias functions (Hoerl and Kennard 1970a, pp. 61–63).

Model 5 gave worst results of all models in table 2, with expected MSE $(\hat{\beta}^*_1) \doteq 85.6$ and MSE $(\hat{\beta}^*_2) \doteq 82.2$ at $k = 0.05$. Even at $k = 0.006$ (not shown in table 2), where MSE is approximately minimized, MSE $(\hat{\beta}^*_1) \doteq 39.3$ and MSE $(\hat{\beta}^*_2) \doteq 39.2$. Since one would ordinarily

Table 2. Expected Values, Variances, and MSE of Estimated β_1 and β_2 Coefficients for OLS versus Ridge Regression where $Y_t = \alpha + \beta_1 X_{1t} + \beta_2 X_{2t} + u_t$, $E(u_t) = 0.5(4) + 0.5(-4)$, and Fixed X_1 and X_2 Take the 5 Values (1,1.2), (2,1.67335), (3,3), (4,4.32665), and (5,4.8) for Models 2, 3, 4, and 5

		Values of k				
		$k=0$ (OLS)	$k=0.05$	$k=0.10$	$k=0.15$	$k=0.20$
Model 2	$E(\hat{\beta}_1^*)$	5.330	4.202	3.976	3.835	3.723
	$E(\hat{\beta}_2^*)$	2.665	3.597	3.635	3.598	3.541
	$E\,\mathrm{var}(\hat{\beta}_1^*)$[a]	54.936	3.190	1.258	0.781	0.587
	$E\,\mathrm{var}(\hat{\beta}_2^*)$[a]	54.936	3.190	1.258	0.781	0.587
	$E\,\mathrm{MSE}(\hat{\beta}_1^*)$	54.936	4.463	3.090	3.015	3.171
	$E\,\mathrm{MSE}(\hat{\beta}_2^*)$	54.936	4.058	2.199	1.652	1.354
Model 3	$E(\hat{\beta}_1^*)$	7.971	4.791	4.304	4.060	3.893
	$E(\hat{\beta}_2^*)$	0.000	2.983	3.284	3.350	3.348
	$E\,\mathrm{MSE}(\hat{\beta}_1^*)$	54.936	13.297	14.701	16.071	17.215
	$E\,\mathrm{MSE}(\hat{\beta}_2^*)$	54.936	12.090	12.045	12.006	11.798
Model 4	$E(\hat{\beta}_1^*)$	9.918	5.220	4.538	4.219	4.011
	$E(\hat{\beta}_2^*)$	−1.984	2.520	3.016	3.158	3.197
	$E\,\mathrm{MSE}(\hat{\beta}_1^*)$	54.936	25.264	30.199	33.264	35.482
	$E\,\mathrm{MSE}(\hat{\beta}_2^*)$	54.936	23.471	26.250	27.221	27.431
Model 5	$E(\hat{\beta}_1^*)$	15.493	6.414	5.174	4.636	4.313
	$E(\hat{\beta}_2^*)$	−7.747	1.142	2.201	2.566	2.725
	$E\,\mathrm{MSE}(\hat{\beta}_1^*)$	54.936	85.620	107.741	118.651	125.586
	$E\,\mathrm{MSE}(\hat{\beta}_2^*)$	54.936	82.201	100.212	107.131	110.236

[a] Variances are all the same for models 1, 2, 3, 4, and 5. Therefore, they are not repeated for models 3, 4, and 5.

not know that $k \doteq 0.006$ was optimal, the use of ridge estimation (without prior information about β_1 and β_2) on a model like 5 would seem quite hazardous!

In the preceding two-explanatory-variable experiments, what would have happened if the β values had been in the same ratio but larger? The answer can be inferred from the earlier equations for the variance, equation (6), and the bias, equation (9). With increased values for the true β values, the bias would be increased proportionally. At the same time, assuming the same error term, the variance for $\hat{\beta}^*$ (and OLS) would remain unchanged. Thus, the advantage in MSE from ridge regression compared to OLS would decrease, since the bias squared of $\hat{\beta}^*$ would increase with the square of the true β values. Of course, increasing (decreasing) the correlation between X_1 and X_2 for the equations used in tables 1 and 2 would cause the relative advantage of ridge regression to increase (decrease).

SELECTION OF OPTIMAL k VALUES

Since the level of k has a marked influence on the MSE of estimated parameters, selection of k is an important consideration. Although there always exists a $k > 0$ such that a smaller MSE can be obtained from ridge regression than from ordinary least squares, the best method for selecting a particular value of k is not obvious. Hoerl and Kennard seem to place the most reliance on the Ridge Trace; they claim that "based

on experience, the best method for achieving a better estimate of $\hat{\beta}^*$ is to use $k_i = k$ for all i and use the Ridge Trace to select a single value of k and a unique $\hat{\beta}^*$" (1970a, p. 65).

Hoerl and Kennard then indicate several considerations that can be used as a guide to a choice of a particular k value: stability of the system as k is increased, reasonable absolute values and signs of the estimated coefficients, and a reasonable variance of regression as indicated by the residual sum of squares.

Hoerl and Kennard (1970b) also illustrate the use of the Ridge Trace by analyzing an empirical ten-factor regression model and a thirteen-factor model. Their heavy reliance upon the stabilization of the Ridge Trace raises the question as to whether a decision rule concerning the stability of the ridge estimates could be formulated. One such rule was defined as follows: "Select a particular value of k at that point where the last ridge estimate attains its maximum absolute magnitude after having attained its 'ultimate' sign, where 'ultimate' sign is defined as being the sign at, say $k = 0.9$" (Brown, p. 29).

For model 1 in table 1, the "ultimate" sign for both coefficients is positive for $k = 0.9$ for every sample. Therefore, the rule reduces to finding the value of k for each sample such that the last individual ridge estimate has attained its maximum positive value. For the first sample in the top part of table 1, $\hat{\beta}_2^*$ declines throughout; therefore, attention should be focused on $\hat{\beta}_1^*$. The value of $\hat{\beta}_1^*$ for sample 1 continues to increase in table 1, reaching 2.548 at $k = 0.30$. However, the maximum value (by increments of 0.05) of $\hat{\beta}_2^*$ is 3.59019 at $k = 0.40$. Using these values, the sum of MSE for $\hat{\beta}_1^*$ and $\hat{\beta}_2^*$ is $(2.57415 - 4)^2 + (3.59019 - 4)^2 \doteq 2.2010$. Similarly, for the second set of estimates from the top in table 1, $\hat{\beta}_1^*$ reaches its highest value at $\hat{\beta}_1^* = 3.475$ at $k = 0.25$, and again $\hat{\beta}_2^*$ declines throughout. The sum of MSE for this sample situation is $(3.475 - 4)^2 + (4.463 - 4)^2 \doteq 0.489$.

One advantage of this rule is that it would insure that different people would select the same k value, in contrast to the somewhat arbitrary Ridge Trace procedure. Following the decision rule for each sample situation and weighting by the probabilities given in the left column of table 1, an expected sum of MSE for $\hat{\beta}_1^*$ and $\hat{\beta}_2^*$ of 1.3076 was obtained. Surprisingly, the selection rule gives a slightly better result than any single value of k listed in table 1. Best result for any single k value given in table 1 is for $k = 0.25$ with an expected sum of MSE of $2(0.686) \doteq 1.372$.

Using the same selection rule for model 2, where $\beta_1 = 5.33$ and $\beta_2 = 2.665$, the expected MSEs were MSE $(\hat{\beta}_1^*) \doteq 3.1629$ and MSE $(\hat{\beta}_2^*) \doteq 1.3279$ so that total MSE $\doteq 4.4908$. Again, the k selection rule gave a surprisingly good result, with the sum of MSE being slightly less than for any single k value.

Considering that the selection rule utilized no prior information, the results of its use on models 1 and 2 were encouraging. However, for models with greater bias resulting from ridge regression, such as models 3 and 4 of table 2, the results from using the preceding selection rule were less satisfactory. Use of the selection rule for model 3 gave a sum of MSE of around 30.1, about 18.6% higher than for the sum of MSE of 25.4 for $k = 0.05$ in table 2.

In summary, the preceding selection rule gave surprisingly good results for models which were "well-suited" to ridge regression, as discussed earlier with regard to expected bias of the ridge estimator in terms of the true β values. Similarly, use of the Ridge Trace should also give fairly good results for models 1 and 2, although the ambiguity of the Ridge Trace for selecting k is a disadvantage. However, an important result is that both the Ridge Trace and the preceding selection rule would give rather unreliable or poor results for models similar to models 3, 4, and 5. Therefore, fairly good prior information about the true β values of the model appears very desirable for benefitting from ridge regression.

Even with no prior information about the true β values, one can gain some insight by testing the hypothesis that the ridge estimates are lower in weak MSE than the nonconstrained OLS estimates, following a procedure used by Ryan and Perrin (p. 13). They selected a value of k where the ridge estimates had stabilized, according to the Ridge Trace, then used Wallace's Noncentral F test. A significant Noncentral F would be a signal that the bias squared could be substantial, and that the model might not be suited for ridge estimation.

IMPLICATIONS FOR LARGER MODELS

The preceding conclusion about the desirability of good prior information for the use of ridge regression on the simple two-explanatory-variable model can be extended to the general linear

model with p explanatory variables, as indicated earlier in the discussion of equation (10). For illustration, consider a three-explanatory-variable model. From equation (10), the bias of the ridge estimate of the coefficient for the first standardized explanatory variable can be written as

$$(12) \quad E(\hat{\beta}_1^*) - \beta_1 = \frac{k\,c_{11}}{|A^*|} [(-1)\,\beta_1 + \hat{b}^*_{12.3}\beta_2 + \hat{b}^*_{13.2}\beta_3],$$

where the notation is the same as for equation (10) except that the longer, but more conventional notation is used to denote the standardized ridge estimates of the coefficients of the equation where X_1 is regressed on X_2 and X_3, that is, where

$$(13) \qquad \hat{X}_1^* = \hat{b}^*_{12.3}X_2 + \hat{b}^*_{13.2}X_3.$$

If X_1 is a positive function of X_2 and X_3 in equation (13), as will usually be the case for economic variables which tend to go up and down together, then the bias in equation (12) will tend to be small if β_1, β_2, and β_3 are all of the same sign and about the same magnitude. Suppose, for example, that $\beta_1 = \beta_2 = \beta_3$ and $R^2_{y.123} = 0.99$. Further, suppose that $r_{12} = r_{13} = r_{23} = 0.99$. Then, $r_{y1} = r_{y2} = r_{y3} \doteq \pm 0.9916652658$ and $\beta_1 = \beta_2 = \beta_3 \doteq \pm 0.332773579$. Thus, for $k = 0.2$ and positive β's, the bias in $\hat{\beta}_1^*$ is

$$(14) \quad E(\hat{\beta}_1^*) - \beta_1 = \frac{0.2(0.4599)}{0.140238} [-0.33277358 + 2(0.45205479)\,(0.33277358)] \doteq -0.02092916.$$

For the preceding model, variance for estimated β_1 by OLS was 0.06677852, if we assume that there were fourteen observations. The corresponding MSE for $\hat{\beta}_1^*$ at $k = 0.2$ would be the variance plus the bias squared or MSE $(\hat{\beta}_1^*) = 0.00024940 + 0.00043803 \doteq 0.00068743$. Thus, MSE of $\hat{\beta}_1^*$ at $k = 0.2$ is only about 1% of that for OLS.

Suppose, however, that for the same explanatory variables as before, $\beta_1 = -\beta_2 = -\beta_3$. Then, for $R^2_{y.123} = 0.99$, we would have $\beta_1 \doteq -0.98518436$ and $\beta_2 = \beta_3 \doteq 0.98518436$. Substituting into equation (12), we obtain

$$(15) \quad E(\hat{\beta}_1^*) - \beta_1 = \frac{0.2(0.4599)}{0.140238} [0.98518436 + 2(0.45205479)\,(0.98518436)] \doteq 1.230374.$$

MSE for $\hat{\beta}_1^*$ at $k \doteq 0.2$ is the variance, 0.00024940, plus $(1.230374)^2$, or MSE $(\hat{\beta}_1^*) \doteq 1.51407$, which is over twenty-two times the MSE for OLS![6]

Clearly, caution in the use of ridge regression on a model with the preceding structure would be advisable. Some prior information about the true β values for $Y = X\beta + u$ would be helpful to determine whether to expect the small bias and small MSE from ridge regression, such as that for the model giving the small bias in equation (14), or whether to expect a large bias and MSE as in equation (15).

Obviously, there are many estimating problems in economics where ridge regression should be used with extreme caution, if at all. For example, in a hypothetical demand function where product price and consumer income have both trended upward over time, these two-explanatory-variables would be positively related to each other. However, if the income effect upon quantity is positive, then the estimate of the positive income coefficient and the negative price coefficient may both be subject to a serious bias if ridge regression is used.

On the other hand, some important estimating problems in economics should lend themselves very well to ridge regression. For example, in the estimation of production functions, the explanatory variables (the inputs) will usually be positively correlated with each other. Furthermore, each productive input usually contributes a positive amount to total value product; otherwise, the manager or operator is being irrational in his or her use of resources. Therefore, from equation (10), ridge regression may provide a powerful new tool to the economist for estima-

[6] One reviewer questioned whether the Ridge Trace would have indicated $k = 0.2$. In fact, the Ridge Trace seemed to stabilize somewhere between $k = 0.03$ and $k = 0.06$. Even at $k = 0.02$, where $\hat{\beta}_1^*$ is still increasing rapidly on the Ridge Trace, MSE $(\hat{\beta}^*) \doteq 1.1729$, which is still almost six times the MSE of OLS! Even if one computes $u = [SSE(\hat{\beta}^*) - SSE(\hat{\beta})] \div 3\ \hat{\sigma}^2$ for $k = 0.02$ (Wallace), $u = 3.85$ is obtained, which is only a modest signal that bias squared is becoming large, since this value is not significant for Noncentral F at the 10% level for the assumed three and ten degrees of freedom (Goodnight and Wallace).

tion of certain types of production functions that have expected positive coefficients, such as for the Cobb-Douglas.

APPLICATION OF RIDGE REGRESSION IN ESTIMATING THE MARGINAL VALUE PRODUCTIVITY OF IRRIGATION WATER

Irrigated agriculture represents not only the dominant consumptive use of water in much of the western United States but also the marginal use (Beattie et al.). Estimation of the marginal value productivity (MVP) of water in the West is obviously important in view of public interest in interbasin water transfer as a means of meeting increased water supply "requirements" for food production and other uses.

Ruttan pioneered the estimation of total value product functions to derive a value for water used in irrigated agriculture, based upon U.S. Census of Agriculture data. This approach has the advantage of being relatively inexpensive, since the data have already been collected and tabulated. Furthermore, estimates based upon these data should, aside from certain difficulties of sampling and estimation, reflect the actually realized irrigation value of the water for the counties of a given region.

Although justifiably acclaimed by the American Farm Economics Association as outstanding published research, Ruttan's book also drew some skepticism concerning certain statistical aspects of the research. Hoch called attention to "a number of difficulties" that tended to mar the empirical results, including omission of relevant variables (pp. 466–70).

In his original formulation, Ruttan hypothesized that six inputs were important variables to include in the production function model. However, only a subset of the original six was included in the final formulation for several of the regions. Presumably, variables were deleted in an effort to overcome numerous problems attributable to multicollinearity—problems of nonsignificance of irrigation-related variables and "wrong" signs.[7] As Hoch noted, this may lead to serious omission-of-variables specification bias, which could distort Ruttan's marginal value productivity estimates.[8] Therefore, we wanted to see if ridge regression could give plausible estimates of the coefficients of Ruttan's complete model from the limited Agriculture Census county data. To conserve space, comparisons of OLS and ridge regression results are presented for only one of Ruttan's "water resource regions"—the Central Pacific region.

THE CENTRAL PACIFIC REGION

This region was composed of twenty-five California counties with more than 50,000 acres of irrigated cropland in 1956 (Ruttan, p. 93). To make the results somewhat comparable to those obtained by Ruttan, a Cobb-Douglas production function was fitted. Estimated coefficients, by OLS and ridge regression, are presented in table 3.

The r^{ii} "variance inflation factors" for variables X_1 through X_6 were 11.2, 18.9, 5.2, 5.2, 2.0, and 5.5, respectively. Perhaps because X_2 was the most highly correlated with the other five explanatory variables, $R^2_{2\cdot 13456} = 1 - (1 \div 18.9) \doteq 0.947$, $\hat{\beta}_2$ took an illogical negative sign. Also, only two variables, X_4 and X_6, were significant at the 5% probability level.

Ridge regression estimates of β_2 appear to be considerably improved, compared to the OLS estimate in table 3. From a nonsignificant negative OLS value, a possibly significant positive value was estimated by ridge regression. "Possibly" should be strongly emphasized (even though the ratio of $\hat{\beta}_2^*$ to its standard error at $k = 0.2$ is $0.2104/0.0607 \doteq 3.47$), since the ridge estimates of variance understate the MSE, as illustrated in tables 1 and 2, because of the bias. Nevertheless, the reduction in variances from ridge regression would seem great enough to offset the bias expected at low k values in table 3.

To illustrate this point, suppose that for estimating MSE of the coefficients at $k = 0.2$, we assume that the OLS estimates are the true values. Then, for our estimate of MSE of $\hat{\beta}_1^*$, we would have variance plus bias squared equal to $0.0563^2 + (0.1723 - 0.2652)^2 \doteq 0.0118$. Thus, for $k = 0.2$, MSE of $\hat{\beta}_1^*$ would be less than one-

[7] This assertion is somewhat speculative because simple correlation coefficients were not published, and high intercorrelation was not stated explicitly as the reason for variable deletion.

[8] Problems of empirical estimation encountered by Ruttan are used for illustrative purposes, and this use is not intended to disparage the significant contribution of his study. Ruttan was careful to note that the grossness of the secondary data in some instances put a considerable strain on the methodology (p. 3). His empirical estimation problems are especially interesting because they are typical of specification problems generally encountered by economists using secondary data sources.

Table 3. Estimated Coefficients for Regression of County Value of All Farm Products Sold as a Cobb-Douglas Function of Inputs, with Comparison of OLS versus Ridge Regression, 25 Central Pacific Counties, 1954

Regression Coefficient	OLS ($k = 0.0$)	Ridge Regression Estimates				
		$k = 0.1$	$k = 0.2$	$k = 0.4$	$k = 0.6$	$k = 0.8$
β_1, Number of family & hired workers	0.2625	0.1735	0.1723	0.1723	0.1691	0.1645
	(0.2093)[a]	(0.0780)	(0.0563)	(0.0387)	(0.0304)	(0.0254)
β_2, Number of tractors	−0.0754	0.1773	0.2104	0.2223	0.2195	0.2135
	(0.3355)	(0.0938)	(0.0607)	(0.0393)	(0.0307)	(0.0258)
β_3, Value of livestock investment	0.0247	0.1186	0.1485	0.1665	0.1692	0.1673
	(0.1587)	(0.0933)	(0.0689)	(0.0469)	(0.0364)	(0.0301)
β_4, Acres irrigated cropland	0.3892	0.2546	0.2147	0.1776	0.1584	0.1459
	(0.1354)	(0.0715)	(0.0564)	(0.0414)	(0.0333)	(0.0282)
β_5, Acres nonirrigated cropland	0.0222	0.0161	0.0130	0.0088	0.0061	0.0042
	(0.0129)	(0.00955)	(0.00818)	(0.00655)	(0.00555)	(0.00484)
β_6, Current operating expense[b]	0.4112	0.3009	0.2585	0.2178	0.1954	0.1798
	(0.1193)	(0.0668)	(0.0484)	(0.0329)	(0.0258)	(0.0216)

Source: U.S. Department of Commerce.
[a] Standard errors are listed in parentheses below regression coefficients.
[b] Included purchased feed, fertilizer, lime, and petroleum products.

third of that for OLS $\hat{\beta}_1$. For most of the other coefficients, a smaller MSE at $k = 0.2$ can be obtained if the bias estimate assumes that the OLS estimates are the true values. Thus, one could argue that the ridge estimates for $k = 0.2$ in table 3 are "better" than for OLS, in the sense that they have smaller MSE in total.

Probably a better evaluation of the ridge estimates in table 3 can be obtained by following the procedure used by Ryan and Perrin (p. 13) to test the hypothesis that the ridge estimates are lower in weak MSE (Wallace). Computing $u = [SSE(\hat{\beta}^*) - SSE(\hat{\beta})] \div 6\hat{\sigma}^2$ for $k = 0.2$, $u = 0.58$ with six and eighteen degrees of freedom; for $k = 0.4$, $u = 1.10$. These values are not significant even for Central F. Thus, this test supplies little evidence to indicate that the problem is unsuited for ridge regression.[9]

The variable having the smallest absolute change in magnitude of its coefficient was X_5, acres of nonirrigated cropland. The reason for the stability of the OLS estimate of this coefficient was its low variance inflation factor, $r^{55} =$ 2.0. As mentioned earlier, the lower the degree of multicollinearity of the explanatory variables, the lower would be the expected gain in accuracy from using ridge regression.

Quite an important reduction in the coefficient for irrigated cropland can be observed in table 3, dropping from the OLS estimate of 0.3892 to 0.2147 for $k = 0.2$ and to 0.1776 for $k = 0.4$. These changes would lower the estimated marginal value product of an irrigated acre from over \$125 per acre to around \$69 and \$57, respectively; similarly, estimated net MVP of irrigation water (MVP of an irrigated acre less MVP of a nonirrigated acre) was lowered from approximately \$77 per acre to \$40 and \$38, respectively.[10]

CONCLUSIONS

Problems of multicollinearity arising from the nature of economic models and data often result in highly unstable and unrealistic estimates of structural parameters, especially if one is restricted to unbiased estimators such as OLS. If this problem is resolved by deleting important variables from the model, one risks a serious omitted-variables-specification bias.

The results of this and other studies (Brown) suggests that we should specify our economic

[9] It is interesting that in their test, Ryan and Perrin (p. 13) rejected the hypothesis that their ridge estimates were lower in weak MSE. This difference in test results would be predicted by the theorem of equation (10). In the quadratic production function used by Ryan and Perrin, the linear coefficients have expected positive signs, and the coefficients for the squared terms should be negative. By contrast, all the coefficients for the Cobb-Douglas function of table 3 are expected to be positive.

[10] MVP calculations based on arithmetic means. Similar results were obtained using geometric means, except for an increase in the nonirrigated cropland MVP.

models fairly completely and utilize available data and various prior information approaches for parameter estimation, rather than using unbiased estimation and mechanically deleting variables to reduce multicollinearity. Ridge regression provides one promising method for alleviating multicollinearity. However, the successful application of ridge regression actually requires considerable prior information. For example, for economic models, where each explanatory variable is a positive function of the other explanatory variables, the best results will be obtained if the true regression coefficients are all of the same sign and of about equal statistical importance.[11] Thus, ridge regression appears very promising, for example, for estimating Cobb-Douglas production functions. However, for those economic models with highly positively correlated variables but with coefficients of unlike signs, some solution other than ridge regression may be preferable. For example, the incorporation of prior information along the lines suggested by Theil and Goldberger or Judge and Takayama may often be more appropriate.

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[11] Equivalently, best results will be obtained if the true standardized regression coefficients are all of the same sign and of about equal magnitude. Also, research to develop improved methods of biased linear estimation holds promise of leading to procedures giving more accurate estimates for a wider variety of models, as indicated by correspondence with Oscar Burt of Montana State University.

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APPENDIX

Expected Bias of the Ridge Estimator for the General Case of p Explanatory Variables

Theorem. The bias of the ridge estimate of the jth standardized coefficient can be expressed as

$$E(\hat{\beta}^*_j) - \beta_j = \frac{k\, c_{jj}}{|A^*|} \sum_{i=1}^{p} \hat{b}^*_{ji} \beta_i,$$

where $\hat{b}^*_{ji} = -1.0$ if $i = j$, and if $i \neq j$, $\hat{b}^*_{ji}$ denotes the ridge estimate of the ith regression coefficient of the model where X_j has been regressed on the remaining $(p - 1)$ explanatory variables. β_i and β_j represent the true regression coefficients in the original model, $Y = X\beta + u$, and c_{jj} is the minor formed

by deleting the jth row and column from $A^* = (X'X + kI)$.

Proof. Note that if we partition A^* so that

$$A^* = \begin{pmatrix} A & B \\ B' & D \end{pmatrix}, \text{ then } \begin{pmatrix} A & B \\ B' & D \end{pmatrix}^{-1} = \begin{pmatrix} A^{-1} + FE^{-1}F' & -FE^{-1} \\ -E^{-1}F' & E^{-1} \end{pmatrix},$$

where $E = (D - B'A^{-1}B)$ and $F = A^{-1}B$, following the notation of Rao (p. 29). The above inverse is easily verified in general by obtaining the properly partitioned identity matrices from $A^*(A^*)^{-1} = (A^*)^{-1}A^*$. For our purpose, we need only consider the case where D (and therefore E^{-1}) are scalars. Then, for standardized variables and $j = p$, equation (7) implies that

$$(16) \quad E(\hat{\beta}^*_p) - \beta_p = -k[-E^{-1}F', E^{-1}]\beta = kE^{-1}[(A^{-1}B)', -\ 1.0]\,\beta.$$

By inspection of A^*, $A^{-1}B = \sum_{i=1}^{p-1} \hat{b}^*_{pi}$. Also, since $(A^*)^{-1} = \frac{1}{|A^*|}(\text{adj } A^*)$, $E^{-1} = c_{pp} \div |A^*|$.

Therefore, the theorem holds for $j = p$. Since the order of an explanatory variable in the equation has no effect on its estimated coefficient in ridge or OLS regression, the theorem is proved.

Discussion. The extreme import and general applicability of the preceding theorem can be seen from the results in appendix table 1. These results illustrate that the bias of the $\hat{\beta}^*_j$ for the model, for standardized variables

$$Y_i = \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \epsilon_i,$$

will be relatively small for positive intercorrelation if, and only if, the true β_j values are all of the same sign and of somewhat similar magnitude.

A surprising result is that the standardized regression coefficients among the explanatory variables can vary greatly without affecting this result, as illustrated by the numbers in the second column (for $k = 0.0$) of appendix table 1. In the first two rows, the standardized regression coefficient between X_1 and X_3 is 0.9874, and between X_2 and X_3 is zero. Note that these two standardized regression coefficients sum to near unity, 0.987421. For the next two rows, at $k = 0.0$, the standardized regression coefficient between X_1 and X_3 $\hat{b}^*_1$, is about four times that for $\hat{b}^*_2$. Again, the two standardized regression coefficients sum to near unity, 0.989746. Finally, for the last two rows at $k = 0.0$, $\hat{b}^*_1$ and $\hat{b}^*_2$ are of equal magnitude. Note further that the standardized regression coefficients again sum to nearly one, 0.991062.

Considering the case for $k = 0.1$, note that the standardized regression coefficients all sum to about the same magnitude for each pattern of intercorrelation among the explanatory variables, ranging from 0.9401 to 0.9436. In terms of the bias as implied by the theorem, if $\beta_1 = \beta_2 = \beta_3$, then for all three cases at $k = 0.1$ in the table, the sum of $\hat{b}^*_1\beta_1$ and $\hat{b}^*_2\beta_2$ would nearly cancel the value of $-1.0\ \beta_3$. This small difference (multiplied by a constant) represents the relatively small bias in this example. This example illustrates that the magnitude of the individual correlations among the explanatory variables makes very little difference, just so long as the overall pattern of intercorrelation is positive—or negative, as discussed after equations (9) and (10).

Appendix Table 1. Behavior of Ridge Coefficients when Third Explanatory Variable, X_3, Has Been Regressed on Explanatory Variables X_1 and X_2, where the True Relation is $X_{3i} = b_1X_{1i} + b_2X_{2i} + \epsilon_i$ and $E(\epsilon_i^2) = 0.025$, $\Sigma x_1^2 = 10$, $\Sigma x_2^2 = 10$, $\Sigma x_1 x_2 = 9.8533$, $\Sigma x_3^2 = 10$, and $n = 13$

Parameter	Distribution of $\hat{b}^*_1$ and $\hat{b}^*_2$ for Several Levels of k			
	$k = 0.0$	$k = 0.1$	$k = 0.2$	$k = 0.3$
$E(\hat{b}^*_1)$	0.987421	0.5332	0.4823	0.4519
$E(\hat{b}^*_2)$	0.000000	0.4069	0.4148	0.4059
Sum	0.987421	0.9401	0.8971	0.8578
$E(\hat{b}^*_1)$	0.791797	0.5091	0.4699	0.4438
$E(\hat{b}^*_2)$	0.197949	0.4332	0.4293	0.4161
Sum	0.989746	0.9423	0.8992	0.8599
$E(\hat{b}^*_1)$	0.495531	0.4718	0.4502	0.4305
$E(\hat{b}^*_2)$	0.495531	0.4718	0.4502	0.4305
Sum	0.991062	0.9436	0.9004	0.8610

INTERNALIZING AGRICULTURAL NITROGEN POLLUTION EXTERNALITIES: A CASE STUDY

GERALD L. HORNER

Alternative policies to achieve a specified nitrogen pollution standard in subsurface irrigation return flows are compared. A system of effluent charges against emitters was the lowest cost and the amount of agricultural commodities produced was less than the alternative policy considered.

Key words: externalities, nitrogen pollution, irrigation return flows.

Development of water resources results in both social benefits and social costs. Social benefits, in terms of food and fiber, are valued in the market place. However, social costs of irrigation wastewater return flows are not valued. In some areas, one of the more detrimental constituents of irrigation return flows is nitrate-nitrogen (NO_3-N). By setting stream water quality standards, the Environmental Protection Agency is administratively attempting to resolve technological external diseconomies caused by nitrogen in irrigation return flows. Although stream quality standards can be established and enforced, the economic impact of the standard will depend upon the amount and distribution of costs incurred to achieve the desired water quality.

The use of an effluent charge to reduce NO_3-N pollution was compared with no control and with the cost of removing NO_3-N by a treatment plant. The objective of this study is to compare income, production, and costs of the water quality control alternatives.

A CASE STUDY: THE SAN LUIS UNIT OF THE CENTRAL VALLEY PROJECT

The San Joaquin Valley in California is divided into two hydrological basins, the San Joaquin and the Tulare. The San Joaquin Basin, located in the northern part of the valley, is drained by the San Joaquin River. The river discharges into the Sacramento-San Joaquin Delta, and eventually flows into the Pacific Ocean via Suisun, San Pablo, and San Francisco Bays. The Tulare Basin, comprising the southern half of the valley, is essentially a closed basin with respect to drainage.

In 1960, the U.S. Congress approved the San Luis Unit of the Central Valley Project on the west side of the San Joaquin Valley in the Tulare Basin. Among other things, the act authorized delivery of 1.09 million acre-feet of water to the 553,000-acre Westlands Water District. At the time of approval, the district was pumping from a rapidly diminishing groundwater supply. The Bureau of Reclamation recognized that a drainage problem existed and, in the authorizing legislation (Public Law 86-488), provision was made for the San Luis Drain to be constructed to export subsurface drainage water from 262,000 acres of land in the district. The San Luis Drain will intercept the irrigation return flow prior to its discharge into both the Tulare Basin and the San Joaquin River and transport the water to Suisun Bay. Exporting the highly saline drainage water from the closed Tulare Basin will eliminate one major problem of irrigated agriculture in the area. Construction of the 188-mile San Luis Drain was begun in 1970 and is expected to be completed by July 1977.

In 1965, the Federal Water Pollution Control Administration (FWPCA) responded to public concern about the possible effects of drainage water being discharged in the Delta and San Francisco Bay. After conducting an investigation, the FWPCA concluded that if the NO_3-N concentration of the drainage water could be decreased from the projected level of 21 ppm to 2 ppm, $11 million could be saved annually—the cost of the damages that otherwise would be sustained by the municipalities and industries, such as commercial fishing and outdoor recreation, which use water from the Bay (U.S. Department of the Interior, p. 5). This estimate was based on the assumption that the present level of waste

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disposal into the Delta and San Francisco Bay would be maintained.

On the basis of this information, the Bureau of Reclamation, the Environmental Protection Agency, and the California Department of Water Resources formed the Interagency Agricultural Wastewater Study Group. This investigative body was to inventory the nitrogen conditions in the potential drainage areas, evaluate the possibility of controlling nitrates at their source, evaluate drainage water quality, determine changes in the nitrogen content of the water during transit, and study the feasibility of various methods of nitrate removal from drainage water. Studies recently concluded indicate that it is technically feasible to remove nitrate from subsurface drainage water by either of two biological processes—algae stripping or bacterial denitrifcation—at a cost ranging from \$30 to \$45 per acre-foot (U.S. Environmental Protection Agency, pp. 22–24). The group ignored alternative economic and institutional approaches to source reduction such as tax-subsidy programs and the legal process.

THE MODEL

Theoretical Considerations: Who Bears the Social Cost?

In 1932, Pigou recognized that external effects were a cause of suboptimal output levels in the economy. He suggested corrective policies, based on taxes or subsidies, to equate prices with marginal social costs,[1] which is suggestive of strong public involvement. Coase debated that in the absence of transactions costs, and where a system of property rights exists, all externalities will be internalized through negotiations. Since Coase's statement, most of the literature has defended policies based on Pigouvian taxes and subsidies to correct the inefficiencies caused by externalities. These policies eliminate the need to consider the transactions costs preventing negotiations and ambiguity of property rights associated with natural resources such as air and water.

Baumol has demonstrated that Pigouvian taxes or subsidies are required for optimal allocation of resources, but that compensation to, or taxation of, those parties affected by the externality should not occur. However, the tax-subsidy approach has not been utilized primarily due to the difficulty of determining the marginal social cost. Baumol and Oates have suggested an environmental pricing and standards approach to the control of externalities. Such an approach involves the establishment of a socially acceptable standard of environmental quality, and subsequent imposition of a system of charges on effluent emissions to achieve the quality standard. This approach will not necessarily yield a Pareto-efficient allocation of resources, but for any given vector of final outputs, the correct set of effluent charges can achieve the standard at the least possible cost.

The polluter, individual or firm, would react to the effluent charge by reducing the amount of effluent released which would in turn result in a higher quality environment. The firm would equate the effluent charge with the marginal cost of all effluent treatment alternatives, as the effluent charge represents the marginal cost of using the environment for waste disposal. The desired level of environmental quality would eventually be achieved by adjustments in the effluent charge. One of the results of increasing the charge may be a reduction of the firm's optimal production level.

Baumol and Oates suggest that the level of effluent charges be determined by iterative adjustments until the desired standard is achieved. One disadvantage of this procedure is the probable occurrence of suboptimal investment decisions. Another drawback is that an environmental quality policy based on effluent charges might not be adopted without a projection of the level of effluent charges required over time to achieve the standard. Additional information, such as an evaluation of the initial reactions of those directly affected and an assessment of the subsequent economic and environmental consequences, is useful in comparing an effluent charge policy with alternative policies. Estimates for the level of effluent charges required over time to achieve a 2 ppm NO_3-N standard in subsurface drainage water from the Westlands Water District are developed in this study. The district and the Bureau of Reclamation are the institutions responsible for the deliveries of irrigation water, the collection of drainage water. If the disposal costs cannot be shifted to the general taxpayer, one institutional objective may well be to minimize the costs of achieving the standard by utilizing the effluent charge system.

Charging the individual farmer on the basis of the NO_3-N concentration in the drainage water from his land would represent the internalization of the social costs or externalities by

[1] Marginal social costs = marginal external costs + marginal private costs.

the responsible economic unit. Since a collective treatment alternative exists, the District must estimate either the level of effluent charge that will reduce the NO_3-N concentrations to achieve the desired quality standard (NO_3-N charge alternative) or the level of effluent charge that will produce sufficient revenue to treat the drainage water (treatment alternative). The cost of achieving the standard by each alternative is not the same. The social cost of nitrogen pollution increases with the concentration of NO_3-N and decreases with the quantity of water. In contrast, the treatment cost alternative, which involves a substantial amount of fixed costs, increases with the quantity of water and increases only slightly with the amount of NO_3-N. The district must select the alternative and the corresponding effluent charge that yield the optimal capital investments in treatment facilities and farm resources over time.

The Empirical Model

A multiperiod linear programming model based on an infinite planning horizon was utilized to derive a set of cropping patterns to maximize the present value of all future returns to land and management, subject to the supply of resources and the cost of subsurface drainage water disposal. The basic model was developed by Isyar to determine an optimum time-path development for irrigation districts in the western San Joaquin Valley. The model was modified for this study by including four alternative fertilizer levels for eighteen crops and six soil types to estimate the quantity and nitrogen content of the drainage water resulting from a given cropping pattern. This configuration of the model permitted changes in the quantity of nitrogen fertilizer applications and the land utilization by soil types in response to charges on drainage disposal. Farmers in the district are able to choose between paying the cost of drainage water disposal or changing or curtailing production practices that produce nitrogen in the drainage water. The optimal policy could involve one or a combination of these outcomes.

Objective function and present value. The objective of the linear programming model was to determine a cropping pattern that would maximize the present value of all future returns to the land and management resources in the Westlands Water District. All returns and costs are discounted to their 1972 value at a rate of 5%. The 5% discount rate was selected because the results would be comparable to those of U.S. Bureau of Reclamation's feasibility studies on the drainage and treatment plant in which the same discount rate was used.

The county average prices for field crops during 1962–70 and 1970 production costs were used to derive objective function values for field crop activities. The future prices of specialty crops were assumed to decrease from 1970 levels due to substantial increases in supply from approximately 426,000 additional acres of irrigated land that will be brought into production in the west side of the San Joaquin Valley between 1968 and 1980 (Dean and King, p. 72). Dean and King have projected future price changes for selected specialty crops, using estimates of price elasticity of demand and projected increases in the demand and supply. The price changes from the 1962 to 1970 county averages used for this study are presented in table 1.

The cost estimates used for removal of nitrate from the drainage water were secured from the California Department of Water Resources (U.S. Environmental Protection Agency, pp. 22–24 and unpublished data). These cost estimates were developed by the Interagency Agricultural Wastewater Study Group in tests at their treatment center in the San Joaquin Valley. The cost function (C) is

$$(1)\ C = \$282{,}144.00 + \$21.52\ W + \$0.12\ Z,$$

where W = the amount of drainage water expressed in acre-feet and Z = pounds of NO_3-N.

Table 1. Estimated Percentage Changes in Prices for 1980 for Selected Commodities Based on Estimated Price Elasticities and "Excess Supply"

Crop	Estimated Elasticity of Demand	Percentage of "Excess Supply"[a]	Percentage Change in Price
Deciduous fruit	−0.65	4.6	− 7.1
Tree nuts	−1.31	6.6	− 5.0
Grapes	−0.23	4.0	−17.4
Oranges	−0.66	2.3	− 7.1[b]
Cantaloupes	−0.50	4.9	− 9.8
Potatoes, early spring	−0.31	13.3	−42.9
Other vegetables	−0.35	2.3	− 6.6

Source: Dean and King (p. 109); Isyar, Moore, and Dean (p. 25).

[a] "Excess Supply" is the estimated production of specified commodities in excess of the quantities that would be demanded at constant prices.

[b] Dean and King assumed price reductions on fresh market sales only. Isyar, Moore, and Dean assumed larger portions to processing.

Nitrogen losses from agricultural operations. The relationship between the amount of nitrogen fertilizer applied, by soil type, and the resultant NO_3-N content of the drainage water was estimated, using ordinary least-squares regression.

The model was applied to cross-sectional data collected in 1967 by the California Department of Water Resources from thirty-eight tile drains in the San Joaquin Valley. The estimated coefficients and their standard errors are

$$(2)\quad \underset{(33.3)}{Y = 218 \text{ Lost Hills}} + \underset{(24.3)}{188.2 \text{ Panhill}} + \underset{(19.9)}{49.3 \text{ Panoche}} + \underset{(0.094)}{0.296X},$$

where Y = the pounds of NO_3-N per acre-foot of drainage water; Lost Hills, Panhill, and Panoche = soil series shift variables with the particular soil series in question having a value of one and others then assuming a zero value; and X = the pounds of nitrogen applied per acre. The numbers in parentheses are standard errors.[2] Twelve other soil series serve as a dummy variable base and are relatively free of natural nitrogen. Equation (2) was used to estimate the amount of NO_3-N resulting in the drainage from cropping activities on different soil types and with alternative levels of nitrogen applied.

Water and land resources. The amount of available resources and the schedule of water costs over time that were used in the linear programming model are indicated in table 2. The present 480,000 acres of irrigated land in the district is expected to increase to 553,000 acres by 1983 as water delivery facilities are completed. Approximately 33,000 of these acres will require drainage by 1979, and this amount will increase to 262,000 acres by the year 2011 (U.S. Bureau of Reclamation, unpublished data).

The 609,000 acre-feet of groundwater presently available for pumping is expected to decrease to 479,000 acre-feet by 1995. Project water deliveries will increase from the present level of 525,000 acre-feet to 1,091,000 acre-feet by 1983. The cost of pumping groundwater is expected to remain constant over time at $22.50 per acre-foot, whereas the price of project water will increase from the present $9.00 per acre-foot to $13.00 by 1979.

EMPIRICAL RESULTS

The costs of achieving the specified quality standard of 2 ppm under each of the two alternative policies are presented in table 3. The cost is defined as the reduction in income plus the costs of treatment due to the standard. Since the objective function of the linear programming model is expressed as the present value of all future returns to Westlands producers, the costs were

[2] The regression was forced through the origin. Without this constraint, the regression is:

$$Y = -27.6 + \underset{(35.9)}{231.9 \text{ Lost Hills}} + \underset{(26.2)}{194.4 \text{ Panhill}} + \underset{(20.5)}{60.1 \text{ Panoche}} + \underset{(0.13)}{0.58X}, \quad R^2 = 0.760.$$

Since negative Y values are unreasonable, a regression line passing through the origin provides realistic estimates for crops with no or very small amounts of nitrogen fertilizer applied.

Table 2. Projected Land Available for Production, Land Requiring Drainage, and Water Availability and Cost in the Westlands Water District over Time

	1972	1976	1979	1983	1988	1995	2005	2010
Available land[a]	480.00	524.00	544.00	553.00	553.00	553.00	553.00	553.00
Land requiring drainage[a]	0	0	33.00	84.00	148.00	213.00	250.00	262.00
Groundwater available[b]	609.00	547.00	508.00	485.00	480.00	479.00	479.00	479.00
Cost of pumping groundwater[c]	22.50	22.50	22.50	22.50	22.50	22.50	22.50	22.50
Project water available[b]	325.00	800.00	1,060.00	1,091.00	1,091.00	1,091.00	1,090.00	1,090.00
Project water cost[c]	9.00	11.67	13.00	13.00	13.00	13.00	13.00	13.00

Sources: U.S. Bureau of Reclamation (unpublished data) and Isyar.
[a] 1,000 acres.
[b] 1,000 acre-feet.
[c] Dollars per acre-foot.

Table 3. Estimates of the Cost to Achieve a 2 ppm NO_3-N Standard on Subsurface Drainage Water in Westlands Water District and the Resulting Resource Use

Average Annual District Values (552,512 acres)	Unit	Without Standard	With Standard: NO_3-N Charge Alternative	With Standard: Treatment Alternative
Total income	$1,000.	40,626.00	40,101.00	39,267.00
Income per acre	$	73.53	72.58	71.07
Total cost of standard	$1,000.		525.00	1,359.00
Cost per acre	$		0.95	2.46
Drained land	acre	83,412.00	56,931.00	58,601.00
Idle land as result of standard	acre		26,481.00	24,811.00
N applied per acre of drained land	lb	54.8	3.7	4.2
Drainage water per acre of drained land	acre-ft	0.67	0.57	0.58
Total drainage water	acre-ft	55,886	32,451	33,989
NO_3-N concentration in drainage water	ppm	20.7	2.0	4.7[a]
Production of:				
Field crops	acre	262,513	254,056	257,900
Fruits, nuts, and grapes	acre	81,902	82,552	82,387
Vegetables	acre	46,799	46,799	46,799

[a] NO_3-N concentration of drainage water prior to treatment.

calculated as the difference between income derived from the optimal cropping pattern without the standard and income derived from the optimal cropping pattern with the standard. Therefore, the total costs of meeting the standard represent those costs associated with reducing farm output or changing agricultural practices and/or those costs associated with constructing, maintaining, and operating a treatment plant.[3]

Total annual income for the district is $40,626,000 if no restrictions are placed on drainage water disposal. Achieving the standard reduced the total income to $40,101,000 utilizing the NO_3-N charge alternative and to $39,267,000 utilizing the treatment alternative. On a per acre basis, the reduction in income is $0.95 and $2.46 for the two alternatives, respectively.[4]

The NO_3-N charge system formulated in this study assumed that the production adjustments would achieve the water quality standard at the lowest possible cost. These results substantiate this statement. Using the NO_3-N charge alternative, the total district cost of achieving the standard is $525,000 annually of which $455,000 is reduced annual income caused by production adjustments and $71,000 is collected by the district in charges. The cost of the treatment alternative is $1,359,000. Of this total, $257,000 represents loss in annual farm incomes and $1,102,000 represents treatment costs. The total cost of the NO_3-N charge is 38.6% of the treatment cost function.

Some of the production adjustments are in the form of reductions in the acreage of field crops. The acreages of other classes of crops remain almost constant, with or without the standard involved. The acreage of field crops estimated under the NO_3-N charge is 8,457 acres less than optimal production without a standard and 4,613 acres less if the treatment alternative is used. Most of this reduction in acreage represents cotton which requires large amounts of water and nitrogen fertilizer inputs relative to some of the other field crops considered, such as alfalfa seed. The change in the crops grown on drained land reduces the nitrogen use from 54.8 pounds per acre of drained land when the standard is not in effect to 3.7 and 4.2 pounds per acre of drained land respectively when the standard is achieved using the two alternatives.

Decreases in the amount of drainage water

[3] These cost figures do not include transactions costs.

[4] The per acre decrease in income is determined using 552,512 acres as the denominator and ignoring the changes in the farm units whose income is directly affected. This will be discussed later.

result chiefly from a reduction in drained land under production, rather than from a reduction in the amount of drainage water per acre. However, the decrease in NO_3-N concentration results from less nitrogen fertilizer use and also from the placement of crops on those soils which minimize the leaching of natural nitrogen. In the case of the NO_3-N charge, the 2 ppm standard is achieved with an average annual charge of $0.42 per pound of NO_3-N. The average revenue collected by the district in achieving the standard is $70,053 annually.

An interesting result is the low NO_3-N concentration of the drainage effluent under the treatment alternative. The 4.7 ppm (table 3) would not seem to warrant construction of a treatment plant to remove an additional 2.7 ppm to meet the standard.[5] Therefore, these results indicate that if the district was going to charge individual farmers to achieve the standard according to the amount of drainage effluent each produced, the NO_3-N charge would probably not only be the lowest cost alternative but would also eliminate the irreversible investment in a treatment plant.[6]

The amount of farmland removed from cultivation due to the imposition of the standard is 26,481 acres if the NO_3-N charge is used and 24,811 if the treatment alternative is used. The displacement of farm families and the lost incomes raises serious equity questions that must be considered. In an economies of size study in Western Fresno County, Moore concluded that substantially all of the cost economies are achieved by farms of about 640 acres in size. Assuming this size of farm is representative of the area, a land area equivalent to about forty-one farms would be lost under the NO_3-N charge system and thirty-nine farms idled under the treatment cost system. Moore also estimated that each farm of this size would generate about $150,000 in annual gross income.[7] The difference in the number of farms lost using one system to achieve the standard versus the other system is probably not significant, but the reduction in farms and loss of aggregate income as a result of the standard (incidence and impact) are social questions that should be considered as a cost of achieving a desired level of water quality. In addition to the loss of farm incomes, reductions in secondary incomes within the region and the welfare effects due to changes in commodity prices could also be considered in evaluating policies to achieve the standard. Certainly policy makers could consider compensating those adversely affected.

SUMMARY

This analysis supports the Baumol-Oates proposition that a specified level of water quality can be achieved at the lowest possible cost by using a system of charges against emitters assuming that transactions costs are equal for each alternative. The resulting allocation of resources is not assumed to be Pareto-efficient as the marginal social cost function is not estimated. The Baumol-Oates pricing and standards approach was applied to determine the least cost policy in achieving a 2 ppm NO_3-N standard on the disposal of drainage water. The cost to achieve the standard using the pricing and standards approach is estimated to be 38% of the cost of internalizing treatment costs.

Imposition of the pricing and standards approach causes some agricultural production adjustments in cropping patterns and resource use. Areas that require drainage but which contain either high amounts of natural nitrates or are relatively less productive than other areas in the district might be left idle. Crop selection in the areas affected by the standard excludes crops that utilized relatively large amounts of nitrogen and irrigation drainage decreases by as much as 93% as a result of the pricing standards approach.

This analysis could be improved by developing more sophisticated techniques for specifying the technical relationships between agricultural production practices (i.e., nitrogen fertilizer amounts, methods and timing of application, irrigation, tillage systems, plant spacing) and the NO_3-N concentration in drainage water. Research should be done to better identify and quantify the parameters of soil systems for the prediction of nitrogen behavior and to develop technological and managerial practices to control the mobility of nitrogen in the soil. Better

[5] The plant is designed to reduce drainage effluent from 20–30 ppm to 2 ppm; very little savings in operating costs result from the treatment of drainage water with lower NO_3-N concentrations. See equation (1).

[6] The possibility of lower cost treatment alternatives designed to remove NO_3-N from drainage water containing 5–10 ppm should be explored. The upper limit on the annual cost for treatment would, of course, be the amount collected from the NO_3-N charge which is $70,053.

[7] The average size land holding for the Westlands Water District is 227 acres. However, seventy-six owners held virtually all of the productive acreage and eighteen firms owned 203,000 acres or 35% of the district (Fellmeth, p. III, 37).

knowledge of these relationships would warrant the consideration of more diverse policies related to an institutional analysis that includes such refinements as the estimation of transaction costs and the social damage functions.

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ECONOMIC CRITERIA FOR FRESHWATER WETLAND POLICY IN MASSACHUSETTS

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The value of wildlife, visual-cultural benefits, water supply, and flood control benefits of wetlands (varied by benefit productivity levels) are determined with help from appropriate scientists. Comparison of benefit value with opportunity cost of wetland preservation is demonstrated as the basis for decisions concerning permits for wetland alteration.

Key words: freshwater wetlands, intangible benefit valuation, environmental preservation, opportunity cost.

A long sustained belief that undeveloped natural resources are unproductive has recently been losing ground. The increasing recognition that such resources often produce benefits of great value to society is evidenced by abundant new legislation designed to help preserve such resources in their undeveloped condition.

The Massachusetts law (Massachusetts 1968, 1972a, 1972b) which requires a wetland owner to obtain a permit from his town conservation commission before altering his wetland is the focus of this paper. Our objective is to develop a generally applicable criterion which can be used as a basis for the public decision to issue or to deny a permit. The basic criterion selected involves a comparison of the social opportunity cost of preservation and the social benefits of preserved wetlands.

IDENTIFICATION AND MEASUREMENT OF OPPORTUNITY COSTS

The opportunity costs associated with preserving a natural resource are the benefits society would receive from the resources in alternative use(s) and which must be foregone to achieve preservation. One possible way to measure opportunity cost is to determine the economic rent produced by former wetlands now in industrial, commercial, residential, and agricultural uses and use it as a proxy for the value to society. This approach leads to complex data collection problems and to tremendous site to site variation. Arbitrary income allocations would be necessary.

An alternative method using the market price of wetlands as an indicator of the opportunity cost of preserving them is used here. Wetlands are assumed to be bought and sold in terms of their perceived economic rent potential in altered uses, since, generally, no income is received by the individual owner from their natural state.[1] If this is correct,

$$\begin{bmatrix}\text{the annual economic rent from}\\ \text{a wetland in its altered use}\end{bmatrix} \geqslant \begin{bmatrix}\text{the annual opportunity cost}\\ \text{of the money paid for it}\end{bmatrix}.$$

The market price of wetlands sold in Massachusetts in 1970–71 varied from a negligible value in remote rural areas to $70,000 per acre in areas of urban expansion near Boston. The minimum price found in urban areas was about $300 per acre. Using 5.375% capitalization rate and these prices, the annual economic rent from or opportunity cost of preserving wetlands varied from $3,762 to $16 per acre in urban areas.

A permit decision using our method requires determination of the market price of the wetland in question. Suitable appraisal methods may include either a comparison with similar and recently sold wetlands or the determination of its site value, by comparison with similar sites, minus the wetland's extra development costs.

MEASUREMENT OF BENEFITS

The task of measuring wetland benefits presents the familiar problem of developing money values for nonmarket, social benefits. Except in special situations, most wetland benefits are nonmarket and broadly received by all members of a community. For purposes of this study these

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[1] A cranberry bog is an example of an exception.

benefits have been divided into four groups: (*a*) wildlife production; (*b*) visual-cultural benefits (i.e., recreational, educational, and aesthetic benefits); (*c*) water supply; and (*d*) flood control potential. Other possible benefits, such as the wetlands' trapping of nutrients and purifying polluted water, have been omitted from the analysis.

Recent efforts to cope with such measurement problems are well illustrated by attempts to determine the social value of outdoor recreation resources.[2] The techniques employed in such studies are essentially an outgrowth of the neoclassical price theory and aim at producing figures of recreation benefits in a manner analogous to pricing of other products and services (movies, concerts, operas) which are traded through the market mechanism. This approach has drawbacks because it does not help in visualizing the total value of a resource to society. Valuations obtained are individual consumption benefits. This deficiency is particularly serious in the case of wetland benefits which are largely external to the on-the-land user.

Monetary measures of wetland benefits must take into consideration the roles of the quality (productivity) of the physical resource and its societal (as opposed to individual) values. To measure benefits economists can use information generated by scientists in other disciplines which identify and quantify those physical attributes of the resource which hold the key to its social value. In this study, data generated by wildlife biologists, landscape architects, and hydrogeologists for wetlands of differing benefit productivity have been used with economic data to estimate monetary values for the four categories of wetland benefits.

Wildlife Values

The measurement of wildlife benefits is based on the possibility that when the market system fails to provide value measurements, the political system, acting through appropriate institutions, can sometimes provide such measures. Wetlands are purchased by state and federal agencies as part of wildlife enhancement programs. Most money for the state purchase is obtained from the sale of licenses to sportsmen who are generally articulate about and politically influential in public decisions involving fish and wildlife. Since this constituency approves these purchases, the amount spent is an indication of the wetland values as seen by sportsmen.

After accepting the purchase price as the politically established value for wildlife and fisheries habitats on wetlands, we were faced with the question of which price paid was the best measure of these values. The market prices of all wetlands in the state with high productivity of wildlife benefits (the only quality considered for purchase in the program) can be placed on a continuum ranging from lowest to highest. The highest price on this continuum which the constituency will accept without strong political objection is the desired measure. The price paid for any specific parcel, of course, is its market price and reflects its current opportunity cost of preservation. The need here, however, is to determine the point on the continuum of market prices above which the land will not be purchased because its price is higher than the capitalized wildlife benefits seen by the constituency. The highest prices actually paid in the program should approach the desired point on the continuum although a "purchasers' surplus" which is omitted in this analysis is possible.

Data on wetland acquisition and management by the Massachusetts Division of Fisheries and Game for more than 8,000 acres bought during 1969–71 were analyzed. Based on the five highest prices, ranging from $2,387 to $584 per acre, a value of $1200 per acre was selected as the capitalized value of wildlife benefits from wetlands with highest quality wildlife characteristics.[3] Addition of the cost of operation, capitalized at 5.375%, raises the value to about $1300 per acre. On an annual basis, such wetlands produce nearly $70 worth of wildlife benefits per acre.

This base figure of $70 was used to establish wildlife values of wetlands with varying productivity. The wildlife biologists develop a quality scoring model which considers ten natural resource variables including wetland class richness, size of the wetland, surrounding habitat types,

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[2] The procedure most widely used for this purpose has been to estimate a demand function, using differential travel costs associated with the locational dispersion of the recreationists as a proxy price variable. These methodologies may be labeled "willingness to pay" approaches and have been used by a number of economists. A few representative studies are Clawson; Goldstein; Helliwell; and Warton.

[3] Selection of the $1200 figure was based on judgment concerning what these five highest prices say about the thinking of sportsmen. Use of the highest figure alone did not seem reasonable, since it is more than double the next highest price yet the selected value needed to be strongly influenced by this highest price since this purchase was accepted by sportsmen.

and wetland juxtaposition (Golet). Using this model, a wetland considered ideal as a wildlife habitat was expected to score a maximum of 100 points. Annual wildlife benefits from such wetlands are valued at $70 per acre per year. Benefits from wetlands with lower scores are valued proportionately lower. Table 1 illustrates this relationship with several sample wetlands.

Visual-Cultural Values

Visual-cultural values are measured in a way similar to that used for measuring wildlife values. Town conservation commissions also purchase wetlands (as well as other land) as open space, and they often receive federal and state subsidies for such purchases. This valuation analysis is based on state-aided purchases since the program is limited to purchases where no active recreation is planned. Each purchase is approved separately by the voters of the town, an essential characteristic of the program for this study. Our methodology assumes that visual-cultural benefits are similar to the open space benefits and are associated, in the minds of the voters, with the typical land purchase decision. Although the state and town usually share the purchase cost equally, the total price for land rather than the portion paid by a town is used as the basis for this benefit valuation because it represents the total social investment.[4]

Table 1. Wildlife Productivity Scores and Benefit Values, Sample Massachusetts Wetlands, 1972

Name and Location of Wetland	Point Scores for Wildlife Values[a]	Value of Annual Benefits Per Acre	Capitalized Value Per Acre 5.375%
White Cedar Bog (Springfield)	51	$36	$670
Otis Fresh Marsh (Otis)	57	40	744
Bear Meadow (Whitman)	68	48	893
Hyannis Wooded Swamp (Hyannis)	70	49	911
Moore's Pond (Warwick)	77	54	1,005
Chicopee River Marshes (Chicopee)	80	56	1,042
Hoosic River Swamp (Cheshire)	83	58	1,079
Lawrence Swamp (Amherst)	90	63	1,172
Wenham Swamp (Wenham)	94	66	1,228

[a] Information was supplied by Francis Golet of the Department of Forestry and Wildlife Management, University of Massachusetts, Amherst. The water chemistry variable was omitted in scoring these wetlands.

The price a town may be willing to pay for conservation lands is a function of many factors such as the economic status of the community, the impending pressures on land use and the community's ability to recognize the same, the physical location of the town, and the educational and professional characteristics of the town population. Although no two communities are identical, the concept of a "maximum" purchase price for open space land in the state as a whole was considered acceptable.

Data on land purchases made by conservation commissions in fiscal year 1972 were collected for twenty-nine municipalities which received self-help assistance from the Division of Conservation Services, Massachusetts Department of Natural Resources for the purchase of forty-five parcels totaling 1,567 acres. Based on the five highest purchase prices which ranged from $5,769 to $3,684 per acre, a figure of $5,000 per acre was selected in the same way as the equivalent wildlife figure as the value of open space land with high productivity of visual-cultural benefits.

With a capitalization rate of 5.375% the public value of visual-cultural benefits from high quality open space land was approximately $270 per acre per year. With the help of cooperating landscape architects, this figure was used to establish visual-cultural benefits of wetlands with varying productivities. They developed a quality scoring model which uses natural resource and cultural resource variables such as land form contrast, wetland type diversity, wetland size, water body size, location of a wetland, and visual and noise pollution (Smardon). The model used for scoring wetlands listed in table 2 was expected to give a score of 120 points to a wetland considered ideal for its visual-cultural values. Thus, a score of 120 was equated to visual-cultural benefits of $270 per acre per year. Wetlands with lower scores are expected to produce benefits with proportionately lower values.

Water Supply Benefits

The approach used for measuring municipal water supply benefits from preserved wetlands compares the cost of wetland water with that of

[4] This issue has not been completely resolved. When voting on a purchase, the voters know that their town will pay only half of the total cost.

Table 2. Visual-Cultural Scores and Benefit Values, Sample Massachusetts Wetlands, 1972

Name and Location of Wetland	Point Scores for Visual-Cultural Values[a]	Value of Annual Benefits Per Acre	Per Acre Value Capitalized at 5.375%
Otis Fresh Marsh (Otis)	33	$ 74	$1,377
Bear Meadow (Whitman)	64	144	2,679
Hoosic River Swamp (Cheshire)	68	153	2,847
Moore's Pond (Warwick)	69	155	2,884
Hyannis Wooded Swamp (Hyannis)	74	167	3,107
Chicopee River Swamp (Chicopee)	102	230	4,279
Wenham Swamp (Wenham)	112	252	4,688

[a] Information in this column was provided by Richard Smardon of the Department of Landscape Architecture, University of Massachusetts, Amherst. Cultural variables were omitted when scoring these wetlands.

an alternative water source. This procedure assumes that water is available from a nonwetland source and that additional water will be needed in the future.

A study done for the U.S. Geological Survey (Cederstrom) calculated the cost at the wellhead of supplying water from well fields in the north Atlantic region. The study considered wells yielding from 300 to 1,400 gallons per minute and ranging from 75 feet to 200 feet in depth. Costs of capital amortization, maintenance, and pumping averaged 2.12¢ per 1000 gallons per day (gpd) in 1968. Adjustment for inflation gave a 1972 cost of 2.44¢. An estimated cost of management (0.33¢) and typical costs of delivery to a central point in town (1.50¢) were added, giving a total cost of 4.27¢ per 1000 gpd.[5]

For many Massachusetts towns, an alternative source of water, if wetlands with water supply potential are altered, is the Metropolitan District Commission. This Commission charges 12¢ per 1,000 gallons delivered to a central distribution point in a town. The 7.73¢ difference between the two delivery costs is assumed to be the value of wetland water. In annual terms, the value is $28.00 per 1,000 gpd. Geologists estimate that about 50% of the wetlands in the state can supply water within the range from 0.25 to 3 million gallons per day (mgd). Assuming a typical wetland producing one mgd to be 10 acres in size, the annual benefits from water supply are $2,800 per acre.[6] If 5.375% is used for the capitalization rate, the value of such a wetland is $52,000 per acre. This value is assumed for a wetland with high water productivity even though it is recognized that some wetlands will produce more than this amount of water.

Flood Control Benefits

The basis for arriving at flood control benefits of preserved wetlands was provided by an Army Corps of Engineers' study of the Charles River Basin in metropolitan Boston (U.S. Department of the Army). The study recommended preservation of 8,422 acres of natural storage areas (wetlands) in the Charles Basin and estimated that by the year 2,000, the resulting annual average flood control benefits (avoided losses) will be $647,000 per year. On the average, the amount of flood damages avoided from preserving these wetlands with assumed "high" flood control potential would be approximately $80 per acre per year.[7] With a 5.375 capitalization rate, the value of an acre of wetland with such flood control benefits is $1,488.

ILLUSTRATIVE CALCULATION OF TRADE-OFF PRICES

Given the benefit estimates, trade-off values can be calculated for use in permit decisions. In this section, the impact of various combinations of high, medium, and low productivities of the four groups of benefits on capitalized values or trade-off prices are presented for illustration. Annual dollar values of four benefit groups at the three levels of productivity used in this calculation are shown in table 3.

Because the four types of benefits are added to obtain a measure of total benefits, the possibility of double counting some benefits must be raised. The main source of possible double counting is between the visual-cultural and wildlife benefits. Some of the open space land purchases, on which

[5] For details of these calculations, see Gupta.

[6] Water productivity of wetlands will vary in the same way that wildlife and visual-cultural benefits vary. Actual productivity, however, can only be determined by drilling test wells. Once test well data for a specific wetland are available, water supply value can be quickly calculated by using this methodology.

[7] This assumption is based on the urban nature of the flood plain and the selection of wetland preservation over dam construction as the better of the two flood control alternatives.

Table 3. Assumed Annual Values of High, Medium and Low Benefit Productivity Levels of Wetlands in Massachusetts, 1972

Type of Benefit	Benefit Productivity Levels		
	High	Medium	Low
Wildlife	$ 70	$ 35	$ 10
Visual-cultural	270	135	20
Water supply	2,800	1,400	400
Flood control	80	40	10

the visual-cultural benefit measure was based, may have explicitly or implicitly involved wildlife benefits in the minds of the voters who approved the purchase. Although the arguments for and against each purchase are not known, the concept of open space seems sufficiently distinct from the concerns of sportsmen to eliminate serious concern about double counting.

Calculations were made using alternative capitalization rates (5.375, 7, and 10%) and time periods (30, 50, and 100 years).[8] Although the concept of "life" has little meaning in the case of land, meaningful economic analysis must have a time horizon. A life of thirty years has been used in the calculations summarized in table 4. This implies that in a dynamic society, preservation decisions probably need to be restudied every generation or so.

The continuation of a property as a wetland clearly can be restudied in the future, but because of the irreversible nature of wetland alteration, restudy of altered wetlands thirty years later has little meaning. Since the social value of preserved wetland appears to be increasing over time relative to general price levels, this irreversibility is of serious concern. Current analysis, for instance, could favor alteration of certain wetlands, while analysis thirty years hence could favor their preservation. The incorporation of this uncertainty into current preservation decisions involves judgment about future value relationships. As a practical procedure, we can only suggest favoring preservation within a range of borderline situations, especially for wetlands producing high levels of benefits.

With the given capitalization rate, if the cost of preserving (purchase price) a wetland is less than the figures in the last two columns of table 4, a permit for its alteration should be denied to maximize social benefits. If its market price is greater than the table figure, alteration is expected to have a net benefit for society. Based on this analysis and our general knowledge of wetland market prices, we estimate that permits for wetland development should be denied on more than 90% of Massachusetts wetlands, although each permit request requires an individual determination.

Use of this methodology for actual permit decisions involves the scoring of wildlife and visual-cultural productivities of wetlands, and the estimation of water supply and flood water absorption potentials. The information is then used to determine a capitalized value per acre of these benefits. The resulting figure is compared with the appraised market value of the wetland per

[8] The computer program was based on discounting the time stream of benefits (including resale of the land) and costs. Although it can handle varying costs and benefit values from year to year, the runs on which table 4 is based assumed constant annual costs and benefits throughout the life of the project.

Table 4. Capitalized Value per Acre of Benefits from Preserved Wetlands with Selected Combinations of Productivity Levels, Massachusetts, 1972

	Level of Benefit Productivity[a]			Capitalized Values of Total Wetland Benefits Per Acre at:	
Wildlife	Visual-Cultural	Water Supply	Flood Control	5.375%[b]	7%[b]
High	High	High	High	$59,900	$46,000
High	High	Medium	High	33,800	26,000
High	High	Low	High	15,200	11,700
High	High	None	High	7,800	6,000
Medium	Medium	None	Medium	3,900	3,000
Low	Low	None	None	700	500
High	Low	None	None	1,800	1,400
Low	High	None	Low	5,300	4,100
Low	Low	None	High	2,200	1,700
Low	Low	High	Low	53,000	40,700
Low	Low	Low	Low	8,300	6,400

[a] See table 3 for the dollar values of high, medium, and low.
[b] Figures have been rounded to the nearest $100.

acre. The benefit values generated here are generally applicable to the state as a whole and may need adjustment to particular communities because of variations in the demand for water and other benefits, the socio-economic and educational mix in the community, and the level of urbanization. They will also need adjustment over time because of both inflation and expected increasing demand for the benefits produced by wetlands.

SUMMARY

This study develops a criterion which can be used as a basis for deciding whether to issue or deny a permit to alter a wetland under the Massachusetts Inland Wetlands Act. The criterion involves a comparison between the social opportunity cost of a denial, as indicated by market price, and the social value of four groups of wetland benefits. Wildlife biologists, landscape architects, and hydrogeologists cooperating with the project provided the methodology for measuring variations in benefits among wetlands. Valuation of wildlife and visual-cultural benefits is based on politically established values while the value of wetland water is based on the cost of an alternative source. Flood control benefits were established by reference to a study of a specific watershed in the state. The analysis suggests that over 90% of the wetlands in the state should be preserved.

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EMPLOYMENT IMPACTS OF THE ECONOMIC DEVELOPMENT ADMINISTRATION'S PUBLIC WORKS PROGRAM

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Improved rural development policy requires empirical analysis of impacts of past programs. Economic Development Administration Public Works Projects in large urban regions had less employment impact than projects in less populated areas. A growth center strategy would have been a poor guide for allocating the funds in this program.

Key words: rural development, public works, employment creation.

The passage of the Rural Development Act of 1972 and the State and Local Fiscal Assistance Act of 1972 marks the beginning of a new era in local-state-federal cooperation in stimulating rural development.[1] Since 1965 the Economic Development Administration (EDA) has been encouraging rural development through business loans, technical assistance to businesses and business groups in rural areas, and public works grants. The Public Works Program provides matching grants to local communities for construction of roads, sewers, water supply systems, and industrial parks. The Program assumes that the provision of these facilities will lead to local industrial growth. As of June 30, 1973, the EDA Public Works Program had provided funds for projects in all fifty states, the District of Columbia, Guam, American Samoa, Puerto Rico, and the Virgin Islands. The Southeast has the most projects (Mississippi—180; Kentucky—167; Arkansas—143) while Guam has but one. The Program has resulted in cumulative construction grants totaling \$1.4 billion (U.S. Dept. of Commerce 1973).

As new rural development funds become available, it is important to understand the experience of past economic development programs for depressed areas. In this research, the employment impacts of the EDA Public Works Program are assessed. Economic theory was used to identify the potentially important variables in explaining the success of public works projects in attracting industry and creating jobs. A multiple regression model provided the basis for examining the influence of these variables on the employment impacts of EDA public works projects.

THE MODEL

Employment creation is usually viewed as an important rural development objective. The employment creation process may be viewed as

$$J = f(x_1, x_2, \ldots x_n, z_1, z_2, \ldots z_m),$$

where J is the number of jobs created by the public program, the x's are the inputs of the public program such as the type of project or total expenditure, and the z's are the conditioning or state variables such as the characteristics of the local area in which the particular project is undertaken.[2] The characteristics of a particular region may affect the success of projects designed to make depressed rural areas more attractive to industry. Likewise, the characteristics of the project and the nature of the firms attracted to the area may significantly affect project impacts. Much of the past work in location theory, export-base theory, income-expenditure theory, and the neoclassical theory of economic growth was used to develop hypotheses about the important regional, project, and firm characteristics influencing project performance (Barrows). The multiple regression model used to examine the hypotheses empirically is

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[1] The Rural Development Act of 1972 is known formally as Public Law 92-419, and the State and Local Fiscal Assistance Act of 1972 is commonly known as the Federal Revenue-Sharing Act, Public Law 95-512.

[2] The project region was defined as the county in which the project was constructed. The terms area, region, and county are used interchangeably.

$$J = \alpha + \beta_1 URB_c + \beta_2 NA_c + \beta_3 Y_c + \beta_4 E_c + \beta_5 M_c + \beta_6 \Delta Y_c + \beta_7 \Delta NA_c + \beta_8 U_c + \beta_9 C + \beta_{10} DC_1 + \beta_{11} DC_2 + \beta_{12} DC_3 + \beta_{13} DT_1 + \beta_{14} DT_2 + \beta_{15} DT_3 + \beta_{16} DI_1 + \beta_{17} DI_2 + \beta_{18} DI_3 + \beta_{19} S_n + \beta_{20} I_n + \beta_{21} G_n + \beta_{22} U_n + e,$$

where J = number of jobs created by the project (first-round impact only); where the regional characteristics are:

URB_c = % of county population living in towns of 2,500 or more, 1970,
NA_c = nonagricultural employment in county (1,000), 1967,
Y_c = average household income in county ($1,000), 1967 (defined as "effective buying power per household"),
E_c = median years education of county population, 1960,
M_c = net migration rate, county, (%) 1960–70,
ΔY_c = growth in county average disposable household income, (%) 1957–67,
ΔNA_c = growth in county nonagricultural employment, (%) 1959–67,
U_c = county unemployment rate, (%) 1960;

where the project characteristics are:

C = total project cost ($1,000),
DC_1–DC_3 = dummy variables indicating project located 21–50, 51–100, or over 100 miles from a city of 250,000 population or more (defined as a "major urban center"),
DT_1–DT_3 = dummy variables indicating project located 21–50, 51–100, or over 100 miles from a city of 25,000 or more (defined as a "major town"),
DI_1–DI_3 = dummy variables indicating project located 21–50, 51–100, or over 100 miles from an interstate highway;[3]

where the firm characteristics are:

S_n = skill index of industry represented by the firm attracted to the region (the index is the national ratio of "unskilled" workers to total employment in the industry, in 1970 [used only in model 2]),
I_n = industry employment growth rate (national), 1958–67 (used only in model 2);

and where the controls for the national economy are:

G_n = GNP growth rate over five quarters bracketing project completion date (one quarter preceding, three quarters following the completion quarter),
U_n = national unemployment rate, average over same five quarters as G_n.[4]

(Sources for the variables are: J, C [U.S. Dept. of Commerce 1970b]; URB_c, M_c, S_n [U.S. Dept. of Commerce 1972]; NA_c, ΔNA_c, E_c, U_c [U.S. Dept. of Commerce 1961 and 1969]; Y_c, ΔY_c [*Sales Mgt.*]; I_n [U.S. Dept. of Commerce 1971]; G_n, U_n [President of the U.S.])

Location theory emphasizes the geographic element in a firm's efforts to minimize production costs (Alonso; Friedmann; Hansen). Firms are attracted to regions because of concentration of inputs or access to an established market for their output. Because these economic advantages are more characteristic of urban areas than rural areas, public works projects located in urban areas should have larger employment impacts than projects located in more rural areas.[5] The variables URB_c, NA_c, Y_c, DC, DT, and DI serve as proxies for these factors.

Location theory, export-base theory, and neoclassical growth theory indicate that the size and quality of the industrial labor force is one indicator of the competitive position of a region. Industrial labor force size may be indicated by the amount of nonagricultural employment (NA_c), but labor force quality is more difficult to define and measure. If it is assumed that years of formal education is proportional to skill level, then median years education of the adult population (E_c) may differentiate between labor forces

[3] The excluded dummy class is the group of projects located 1–20 miles from a major city, town, or interstate highway. The regression coefficients on each dummy variable may be interpreted as the increase in jobs created by "moving" a project from the 1–20 mile class to each of the other rings, *ceteris paribus*.

[4] Most of the data were not available on an annual basis, so an attempt was made to collect as much of the data as possible for a single year, 1968, in which most of the projects were completed. Some data refer to the period 1960–70 and may, therefore, have been influenced by project impacts. This influence is likely to have been slight because (*a*) the projects were completed late in the decade (1967–69) and would not have had sufficient time to substantially affect the regional data, and because (*b*) most projects were small relative to the amount of economic activity in the area.

[5] The U.S. Census definition of "urban" was used in this study, and hence any village or town of over 2,500 population is considered an urban place. The degree of urbanization is measured by the percentage of the county population living in towns of 2,500 or more.

in various regions. The recent growth history of industry attracted to a project may be crucial and is included in the model (I_n).

An alternative model for regional income determination is an income-expenditure analysis based on Keynesian theory (Barrows). The income-expenditure theory suggests that several variables are important in determining project impact: the amount of government expenditure in the area (total project cost—C), conditions in the local labor market (unemployment rate—U_o, and labor skill levels—E_c), trends in growth of GNP (G_n), and unemployment in the broader national economy (U_n).

A neoclassical model emphasizes the role of increased factor productivity in regional economic growth and concentrates on factor proportions and the efficient allocation of capital and labor between sectors and regions. It further suggests that employment impacts will be larger in regions with a growing labor force since firms may be attracted by a growing labor force. At any level of labor force skill and demand, a growing labor force may be expected to receive lower wages than a contracting labor force, thus encouraging firms to expand their production and substitute labor for capital whenever possible. The rate of net migration (M_o) was used as a proxy for labor force growth.[6] Neoclassical theory also suggests that the labor skill requirements of the firms attracted by the project (S) will influence employment impacts. It was hypothesized that low-skill industries tend to be more labor-intensive and thus have larger employment impacts, *ceteris paribus*.

Finally, investment decisions may be influenced greatly by the state of business confidence, the "animal spirits" of Keynes and Robinson. The rate of growth in GNP (G_n) and the national unemployment rate (U_n) were used to reflect business confidence on a national scale. For a small region, business confidence may be a function of the past economic performance of the area. Three variables were used as proxies for business confidence in the local economy—the unemployment rate (U_o), the recent growth in nonagricultural employment (ΔNA_o), and the growth in disposable household income (ΔY_o).

[6] Migration is not a perfect proxy for labor force growth but over several years will closely reflect change in employment opportunity. Other proxies such as total county employment are less satisfactory because they do not incorporate changes in labor force participation rates and unemployment.

EMPIRICAL ANALYSIS

The Data

Economic Development Administration (EDA) evaluations of its Public Works Projects were used to establish the employment impacts of the projects. The EDA evaluations were carried out in 1972 and included projects completed in 1967–69. The intervening three years after all projects were completed was sufficient time for the initial employment impact of the projects to be realized. The EDA evaluation reported only the first-round impacts of the projects; second and higher-round impacts were not reported and were therefore not included in the analysis (U.S. Dept. of Commerce 1970a, 1970b).[7] In addition, construction impacts were not included, so that a public works project is considered to have had an impact on regional employment only if it attracted some firm to the region.[8]

Empirical Results

The empirical results were developed in several stages. First, multiple regressions of employment impact on regional, project, and firm characteristics were conducted. These regressions indicated that the employment impacts were greatest in urbanized counties outside large metropolitan regions. This result was not entirely consistent with hypotheses derived from economic theory, and an analysis of the residuals suggested that further statistical analysis might illuminate some of the relationships suggested by the multiple regression model. First, the results suggested that it might be possible to clearly distinguish between projects which created jobs and those which did not—potentially valuable information for policy decisions. Discriminant analysis was used to derive a linear combination of regional and project characteristics which could distinguish between projects with high or low employment impact. The discriminant analysis and the analysis of the

[7] First-round impacts include only that employment directly attributable to the project, i.e., the number of jobs in the firm attracted by the project. To the extent that regional employment multipliers are a function of the concentration of economic activity and degree of urbanization in a region, the use of first-round impacts instead of total impacts will underestimate project impact in urban/industrial regions relative to rural/agricultural regions.

[8] It is possible that some of the employment generated by the EDA project would have gone to another region in the absence of the project or that other regions lost employment due to relocation of a firm in the project region, even though EDA policy discourages this employment "piracy."

residuals of the original multiple regression model suggested that important interaction effects were present among the independent variables. The Automatic Interaction Detector (AID) program was used to identify these interaction effects, and the important interactions were introduced into a second generation multiple regression model.

Multiple Regression Model 1

One notable result of model 1 is the magnitude, and sign, of the coefficients on the dummy variables for distance of the project from a major city, town, or interstate highway (table 1).[9]

[9] The significance of the coefficients in models 1 and 2 is an indication of which variables may be more important in predicting project impacts and which types of variables may merit special investigation in future rural development research. Significance levels should not be overemphasized because the magnitude of influence of independent variables is of primary interest, and in addition, a series of t-tests performed on each coefficient is not equivalent to a single F-test performed on the group (Freund). Finally, the results of previous

Table 1. Results of Regressions of Number of Jobs Created by Project on Regional, Project, and Firm Characteristics

	Model 1		Model 2		Model 3	
Variable	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
Regional characteristics						
URB_o	2.049[a]	0.686	3.980[a]	1.072	2.436[a]	0.722
NA_o	− 0.106	0.237	− 0.391	0.468	− 0.027	0.208
Y_o	− 17.223	14.745	6.265	21.835	− 11.217	14.448
E_o	− 20.970	14.841	− 67.608[a]	24.814	− 29.226[a]	13.224
M_o	1.669	1.107	4.413[a]	1.467	1.795[a]	0.953
ΔY_o	45.766	32.260	33.465	38.187	22.245	28.256
ΔNA_o	− 44.288	51.140	− 68.584	54.432	− 23.731	43.160
U_o	− 2.291	3.956	3.667	6.132	− 3.909	3.560
Project characteristics						
C	0.014	0.013	0.022	0.018	0.029[a]	0.014
DC_1 ($n = 33$)	136.978[a]	46.607	170.695[a]	77.853	246.708[a]	46.529
DC_2 ($n = 36$)	77.938[a]	47.177	33.327	80.116	160.396[a]	46.283
DC_3 ($n = 65$)	95.954[a]	46.829	70.185	78.638	207.015[a]	47.740
DT_1 ($n = 65$)	− 14.011	32.135	7.640	42.355	− 61.821[a]	28.628
DT_2 ($n = 24$)	41.440	43.076	67.013	55.794	20.329	116.063
DT_3 ($n = 8$)	130.730[a]	69.205	172.269[a]	91.901	131.329	133.736
DI_1 ($n = 41$)	29.396	29.934	68.400	40.722	7.151	26.582
DI_2 ($n = 12$)	− 15.025	51.105	31.907	64.292	17.380	44.147
DI_3 ($n = 8$)	−119.204[a]	64.600	−203.738[a]	114.169	−162.388[a]	56.093
Firm characteristics						
S_n			145.362	96.124		
I_n			3.089	4.739		
Controls						
G_n	410.501	316.744	768.119[a]	454.710	432.977	271.484
U_n	43.735	43.954	88.633	75.873	28.975	37.328
Interaction variables						
Group A					111.685[a]	46.149
Group B					111.636	129.336
Group C					128.729[a]	77.105
Group D					−100.656[a]	50.488
Group E					97.695	135.272
Group F					− 86.959	120.823
Group G					−259.200[a]	59.082
Group H					−156.449[a]	56.012
Sample Size	155		97		155	
R^2	0.19		0.40		0.46	
F-Ratio	1.54		2.24		3.86[a]	

[a] Significant at 0.90 level of confidence. Significance levels are meaningful only in models 1 and 2, and then only if the reader recognizes that a series of t-tests on individual coefficients is not equivalent to a single (F) test on the entire regression equation—all coefficients taken as a group. In model 3, the results of the discriminant and AID analysis were incorporated in the model specification, so significance tests cannot be used as a single criteria to identify "important" variables. For further discussion, see Freund.

Since the excluded class is those projects within 1–20 miles of city, town, or interstate, the coefficients indicate the effects of "moving" a project from the 1–20 mile area to a more distant ring, *ceteris paribus*. In general, projects located in or very near major cities (250,000 population or more) were less successful in creating jobs than projects located further from major urban centers. This result was substantiated by other regressions in which the bounds of the dummy classes were varied, and in others in which the distance variable was included in logarithmic, reciprocal, and linear form. The distance-from-town (25,000 population or more) variable behaved in a similar manner, and only the interstate highway variable showed the expected relationship between distance and project impact. The magnitude of the distance coefficients is quite large; their effect on project impact was considerable.

But the percentage of urban population was positively related to project impacts, a seeming contradiction of the distance variable results. Since any village of over 2,500 is defined as urban, the results may be interpreted as follows: employment impact increased with distance of the project from a major city or a major town and increased as the population of these more distant counties became increasingly concentrated in towns of 2,500 or more.

Thus, projects which were most successful in creating jobs were those located outside major cities or towns, in counties which have been experiencing rapid growth in income and population and in which population is concentrated in towns of 2,500 to 24,999.

Multiple Regression Model 2

In order to examine the influence of firm characteristics on employment generation, the sample was limited to the ninety-seven projects which created at least one job. The coefficients on most of the variables did not change greatly, although both the absolute value and significance of the education and migration coefficients increased (table 1). The results indicated that firms using more unskilled labor were associated with larger employment impacts, as expected, but the coefficient on industry growth rate was quite small and not significant.

Another interesting change from model 1 is the increase in the F-ratio from 1.54 to 2.24 and the corresponding increase in R^2 from 0.19 to 0.40.

analysis were used in specifying model 3, and thus the t-test is not legitimate as a rigorous hypothesis-testing tool for model 3.

These changes may be explained in two ways; either (*a*) the regression model may perform better in explaining the number of jobs created within the class of successful projects than in discriminating between successful (some impact) and unsuccessful (no impact) projects; or (*b*) the increase in F-ratio and R^2 is due solely to the decrease in sample size relative to the number of explanatory variables. If the first interpretation is correct, then the regressions suggest that it may be possible to construct a profile of the typical project which has some employment impact. The profile would be based on regional and project characteristics and could be constructed by use of discriminant analysis.

Discriminant Analysis

Although it is useful to examine project success in an *ex post* analysis, improved rural development policy requires an ability to predict project success in an *ex ante* analysis. The regression results suggested that it may be possible to distinguish between regions associated with successful or unsuccessful projects. Discriminant analysis is a means of making such a distinction on the basis of regional and project characteristics (Cooley and Lonres). The projects were divided into two groups—those creating no jobs (group 1) and those creating at least one job (group 2). Discriminant analysis was used to derive a linear function of the regional and project characteristics which maximizes the between-group sum of squares relative to the within-group sum of squares (table 2). The coefficients of the dis-

Table 2. Discriminant Function and Scaled Coefficients for Distinguishing between Projects Creating No Jobs (Group 1) and Projects Creating at Least One Job (Group 2)

Variable	Discriminant Coefficient	Scaled Coefficient
Total Project Cost ($)	0.00[a]	+11.67
County Unemployment (%)	−0.45	−16.47
Migration (%)	−0.03	− 5.48
Nonagricultural employment (1000)	0.00[a]	− 1.63
Median years education	−0.36	− 6.17
Urban population (%)	+0.02	+ 7.06
Median income ($1000)	−0.81	−15.70
Poor households (%)	−0.05	− 7.44
Distance from interstate	−0.04	− 9.40
Distance from town	+0.02	+17.43
Distance from city	+0.01	+12.54

Note: Group 1 mean discriminant value = −13.23, Group 2 value = −11.91. Critical value (using overall means) = −12.39. Latent root = 0.1663, 100% of trace.
[a] The actual coefficient is greater than zero but was rounded.

criminant function may be multiplied by their respective standard deviations to obtain a set of scaled coefficients which show the relative contribution of each variable to the function. Since the calculated centroid of group 1 lies to the left of that for group 2 on the discriminant index line, negative scaled coefficients indicate that regions which exhibit large values for that variable tend to be associated with projects which created no jobs. The scaled coefficients indicate that the most important variables in assigning an observation to group 2 (some impact) are distance from town, distance from city, total project cost, and percentage of urban population. The most important variables in determining membership in group 1 (no impact) were county unemployment rate, median household income, and distance from interstate highway. These results closely parallel the previous regression results, although the importance of project cost, county unemployment, and median income was not brought out by the regression analysis. This suggests that there may be important interactions between these variables which were not incorporated in the regression analysis (Cooley and Lonres, pp. 243–45). In general, discriminant analysis proved to be a useful tool in distinguishing between regions with high-impact and low-impact projects. The ideal model would incorporate the interaction effects suggested by discriminant analysis into a regression framework so that the number of jobs created could also be predicted.

Interaction Effects and Regression Model 3

Automatic Interaction Detector (AID) was used to identify important interactions among the independent variables, as suggested by the discriminant analysis (Sonquist, Baker, and Morgan). AID requires a dependent variable and a set of predictor variables, each divided into several classes (Hermann). The program examines all possible divisions of the sample according to every predictor class and selects that predictor-and-class division which maximizes the between-group sum of squares when the sample is split (Sonquist, Baker, and Morgan, p. 9). The program repeats this procedure for each of the subsamples and continues until group size or variance explained by further divisions decreases below some specified minimum.[10]

The dependent variable in the analysis consists of the residuals from the regression in model 1. The use of the residuals was justified because only the interaction effects were of interest, and none of the interaction effects were captured in the original model. The predictors were regional and project characteristics. The results are presented in figure 1, where high absolute values for the mean of the residuals in a group indicates strong interaction effects among the variables defining the group.

In general, the results confirm both the interactions suggested by the discriminant analysis and the arguments advanced to explain the regression results. There is clearly a large interaction between income and county unemployment (groups C, G, and H), as suggested by the discriminant analysis. Group C includes areas with high income and high unemployment; group G includes areas with high incomes, average or low unemployment, located 21–50 miles from a major city; and group H is similar to group G except that projects were located more than 50 miles from a major city. Based on a detailed examination of the counties composing each group, areas in group H were characterized as satellite cities and areas in group G as growth centers. Group A was characterized as large urban or industrial regions, groups E and F were isolated rural areas, and group B represented small but urbanized counties far from towns of 25,000 or more. Counties in group D were similar to those in group B except that the project was located within 50 miles of a major town.

The groups identified by the AID analysis are similar to those defined by Cameron in his analysis of the types of areas receiving EDA assistance (pp. 70–77). The groupings in the Cameron analysis were associated with different economic growth histories and different economic development needs. The observations in groups C and H are similar to Cameron's High Income-Rapid Growth class, with group C including towns dominated by a single industry and group H approximating the rapid growth areas of the east and west coasts. Group A is similar to Cameron's "Old Industrial" grouping, and groups D, E, and F would be included in the "Not-So-Poor Rural Areas" defined by Cameron.

The regression results suggest that projects in heavily populated counties very close to major cities created few jobs and that projects in

[10] Since the sample size in this study is relatively small ($n = 155$), the minimum bound for variance explained was set at a higher level than usually recommended. The stability of the AID results was tested by varying the classification bounds on the predictors, and it was found that the final groups changed only slightly with different predictor bounds.

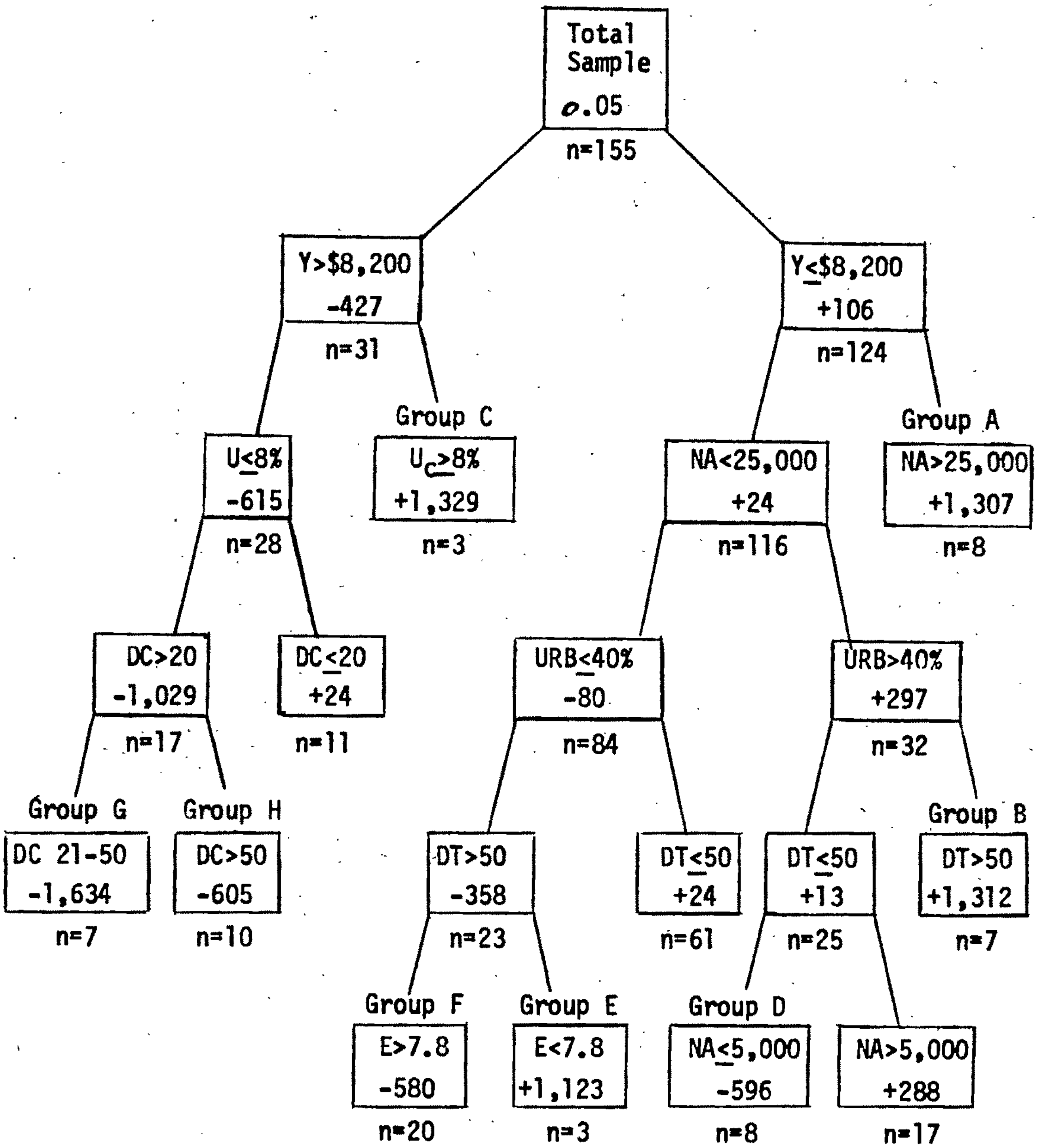

Figure 1. Results of AID analysis of residuals from employment impact regression

Note: The number in the bottom of the box is the average value of the residuals for that group. The abbreviations in the top of the box represent the variable on which the class was divided, where Y = average income; U_c = county unemployment; URB = urban population (%); DC, DT = distance to city, town, respectively; E = median years education; NA = nonagricultural employment.

sparsely populated but urbanized counties far from large towns or cities created many jobs. The AID analysis indicates that substantial interactions exist which reinforce these basic trends, and confirms the interactions between average household income, county unemployment, and distance-to-city variables suggested in the interpretation of the discriminant analysis.

The interaction effects identified by the AID analysis were introduced into the third regression model in the form of dummy variables (see table 1). The sign of the mean residual for each group was the expected coefficient sign when the group was used as a dummy variable. The inclusion of interaction terms did not greatly change the estimated coefficients and does not greatly alter the

previous conclusions. Impacts were greater for projects located outside major metropolitan areas in counties in which population is concentrated in small towns of 2,500 to 24,999. The interaction terms, especially groups G and H, reinforce this basic conclusion.

Job creation impacts do not seem to be related to distance from a major town in any systematic manner. Although projects located over 100 miles from a major town had more employment impact than projects within 20 miles, projects in the 21–50 mile ring had less. In examining the interaction terms, especially groups B and F, the critical factor is not distance from major town of 25,000+ population, but whether the population in these isolated rural areas is concentrated in small villages of from 2,500 to 24,999. Increasing concentration means increased job impacts, *ceteris paribus*.

Household income and median years of education were negatively related to job impacts, a consistent result since both are at high levels in large urbanized areas. However, the magnitude of both coefficients was relatively low. Large job impacts were associated with higher net migration and income growth, but negatively associated with growth in nonagricultural employment. This may be partially explained by the fact that many essentially rural areas have been experiencing rapid growth in income and population from 1960 to 1970, and those located 21–50 miles from major cities have not been experiencing employment growth in proportion to growth in population and income. However, the magnitude of all of the coefficients is low, the significance levels were low in model 1, and a reasonable conclusion is that they had relatively little effect on employment impacts.

The importance of total project cost was brought out by the inclusion of interaction terms, as suggested by the discriminant analysis. However, the magnitude of the coefficient is quite low, indicating that a marginal addition of $100,000 would create only 2.9 jobs, *ceteris paribus*. In general, the conclusions are not greatly different from those of model 1.

CONCLUSION

These results have several implications for economic development policy. Economists (Alonso; Cameron; Hansen) have argued that public agencies should concentrate development investments in fairly large urban centers—the growth center strategy. The empirical analysis in this study indicates that EDA investments in large urban centers or regions did not produce employment impacts as large as projects located in less densely populated areas. This suggests that counties should not be eliminated from consideration for development investments simply because they do not contain an urban center of over 25,000 population. A new criteria for development assistance might exclude rapidly growing urban counties from direct development investments. Instead, programs in these areas might concentrate on manpower training and labor-market information to help reduce unemployment by matching new jobs with previously unemployed local residents.

The policy of public investment in severely depressed regions or isolated rural areas has been criticized as an attempt to aid regions in which there is little hope of attracting industry or supporting continued growth. This study indicates that employment impacts of public works projects were relatively large in many counties which might ordinarily be considered beyond hope. An important policy implication is that until a comprehensive and empirically tested theory of rural development emerges, an agency is well advised not to base its entire development effort on a single strategy. Instead, a rural development agency implementing a new program should employ several strategies with emphasis on an early evaluation of these competing approaches.

That conventional development theory would have been a relatively poor guide for policy decisions in the EDA case implies that there is a critical need for more empirical research in domestic economic development. A series of empirical studies is needed to evaluate the most effective development policies to attain particular objectives in different regions. From these studies, an integrated theory of economic development may be constructed, based on empirical observation and selective modification of existing economic growth theory.

Finally, a word of caution is in order. The data used in this study are limited to a particular type of development project (public works) administered by a single agency, and the results may not be generalizable beyond this narrow population. Second, the study includes only those counties which were able to obtain EDA assistance—counties which had a core of leaders who were able to organize and maneuver a project application through the bureaucratic channels. These same leaders may have been equally aggressive in seeking new industry, so the counties used in the study may not be representative of all counties with the same economic characteristics.

Finally, second and higher-round employment impacts were not incorporated into the study, and their exclusion results in a downward bias in the estimates of impacts in large urban areas. Accordingly, this study should be viewed as but a first step toward identifying the economic development impacts of public investments, and the results must be verified by other empirical investigations of economic development efforts.

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A SPATIAL AND TEMPORAL MODEL OF THE NORTH AMERICAN PORK SECTOR FOR THE EVALUATION OF POLICY ALTERNATIVES

LARRY MARTIN and ANTHONY C. ZWART

A quarterly recursive quadratic programming model of the North American pork sector is constructed to explain spatial and temporal variations in the sector and to evaluate the repercussions of policy changes. The model incorporates econometric supply, demand for consumption and demand for storage equations for Eastern and Western Canada and the United States. It is then run over a forty-one quarter period to evaluate its ability to simulate the sector. A policy experiment is conducted which assesses a change in tariff policies between Canada and the United States to illustrate the model's application for policy analysis.

Key words: pork, supply response, demand response, quadratic programming, policy analysis.

Several important issues face Canada's livestock sector at the present time. Among these are possible changes in trade arrangements resulting from G.A.T.T. negotiations, imminent changes in domestic transportation and marketing policies for feedgrain and livestock products, and the decision of the federal government to enhance the strength of agricultural stabilization programs. No empirical framework has been available in Canada which would allow an evaluation of such policy changes on the general level of prices, regional production, and trade.

A model of the North American pork sector which can be used to evaluate alternative policies in the Canadian subsector is presented in this paper. The model is based on static spatial equilibrium theory but includes dynamic elements through the incorporation of lagged endogenous variables in supply and storage demand functions.

First, spatial and temporal characteristics of slaughter supply, wholesale demand, and demand for storage stocks are discussed, and econometric estimates of these relationships are presented. Second, the econometric functions are combined into a recursive mathematical programming model which is based on the formulation of Takayama and Judge (1971). Third, the model is validated by comparing solutions generated by the model to actual market observations for a forty-one quarter period. Finally, the model is used to evaluate a change in tariff policy as an illustration of its potential usefulness for policy analysis.[1]

MARKET CHARACTERISTICS AND ECONOMETRIC ANALYSIS

The model constructed for our analysis includes three supply and demand regions—Eastern Canada, Western Canada, and the United States.[2] Two Canadian regions are included because, as Kerr has shown, Western Canadian supply is relatively unresponsive to changes in hog prices as compared with that of Eastern Canada. However, his analysis showed that Western Canadian supply is very sensitive to

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[1] Since the major objective of this paper is to discuss the mathematical programming model and its potential applications, a rigorous discussion of the econometric analysis is not presented. However, the signs on all the regression coefficients are consistent with theoretical expectations and the elasticities are consistent with those obtained in other studies. A more thorough examination of the economic structure and econometric techniques implied by this analysis is presented by Meilke, Zwart, and Martin; Zwart; and Zwart and Martin.

[2] Eastern Canada includes Ontario, Quebec, and the Atlantic Provinces. Western Canada includes the Prairie Provinces and British Columbia.

changes in stocks of Western feedgrains above Canadian Wheat Board quotas. Thus, different supply response models are required for the two regions. Second, the extreme geographical separation of the two regions clearly delineates them as individual trading regions.

The United States is included in the model because of its importance to the Canadian market. Data contained in Statistics Canada (*Livestock and Animal Product Statistics*) and U.S. Department of Agriculture (*Livestock and Meat Statistics*) show that the U.S. is Canada's most important trading partner for pork. During the 1960s, it purchased approximately 90% of Canada's exports of pork and provided a similar percentage of her imports. The level and direction of trade between the two countries is closely related to their relative prices, which suggests that arbitrage occurs when price differentials between the two countries exceed transfer and tariff charges.[3]

Slaughter Supply Characteristics

Previous studies of the pork sector (Crom; Harlow; Kerr; Pando) suggested that the major determinants of hog supply are producer expectations of hog prices, feedgrain prices (or feedgrain stocks in Western Canada), the profitability of competing enterprises (beef), and seasonality. Seasonality is of particular importance in the pork sector since some producers have traditionally adjusted farrowings to avoid adverse winter weather conditions. Based on these studies, quarterly supply equations were estimated for each region using data from 1961 through 1972. The supply equations were estimated with the geometric lag specification suggested by Nerlove. Variables included in the econometric models are defined and data sources for each are shown in table 1.

The monetary variables used in the U.S. supply equations (as well as the U.S. demand for consumption and stocks equations discussed below) are converted to Canadian currency.[4]

[3] One additional market characteristic must also be included in the analysis. Hawkins, Bennett, and Boswell have shown that a substantial part of Canada's exports to the U.S. (approximately sixty million pounds per year of heavy hams) constitute a specialized market in the Eastern U.S. which is not responsive to price changes. The manner in which this is dealt with in the model will be explained below.

[4] The supply functions are expressed in terms of the quantity of pork, not the quantity of hogs. Thus, the supplies are consistent with the demands discussed below.

Table 1. Variables in the Econometric Equations

Variable Notation	Variable Identification
QS	Quantity of pork slaughtered (million pounds, cold, trimmed weight) in each region per quarter.[a]
PH	Quarterly average price of slaughter hogs (Index 100 hogs at Toronto and Calgary for Eastern and Western Canada respectively, and average of Seven Markets for good barrows and gilts for U.S.). U.S. prices are adjusted to Canadian dollars and converted to carcass, instead of live weights.[a]
PF	Feed price. In Eastern Canada, a weighted average of feedgrain prices. In the U.S., a weighted average of hog feed (0.88 times price of corn plus 0.12 times price of 44% soybean meal at Decatur, Illinois).[b]
FS	Feed grain availability in Western Canada. Specified as stocks of wheat and barley on farms in the Prairie Provinces at March 31.[c]
BPD	Opportunity cost for hog production. Specified as the margin, price of good slaughter steers minus good feeder steers (Toronto, Calgary, and Omaha respectively for the three regions).[a]
$\frac{QD}{C}$	Quarterly per capita consumption of pork (pounds) in each region.[a]
IS	End of quarter cold storage stocks of pork (million pounds) in each region.[d]
PP	Quarterly retail poultry price index.[e]
PB	Retail beef price index for Canada and average retail price of beef for U.S. (in Canadian dollars).
Y	Per capita disposable income (in Canadian dollars for the U.S.).[f]
D^g	Quarterly intercept dummy variables included to account for seasonality.
Subscript convention $t-i$	Refers to variable lagged i quarters.

[a] From Canada Department of Agriculture; U.S. Department of Agriculture (*Livestock and Meat Statistics*).
[b] From Statistics Canada (*Coarse Grains Quarterly*); U.S. Department of Agriculture (*Feed Statistics*).
[c] From Statistics Canada (*Coarse Grains Quarterly*).
[d] From Statistics Canada (*Stocks of Frozen Meat Products*); U.S. Department of Agriculture (*Livestock and Meat Statistics*).
[e] From Statistics Canada (*Livestock and Animal Product Statistics*); U.S. Department of Agriculture (*Food Consumption, Prices, and Expenditures*).
[f] From Statistics Canada (*Canadian Statistical Review*); U.S. Department of Commerce.
[g] Slope dummies were also included for the price variables in earlier runs of the supply, demand for consumption, and demand for stocks models to determine whether there are seasonal differences in supply response. The resulting F-statistics were very low and the hypothesis that there is seasonality in response to price changes was rejected.

This is done because a common currency must be chosen so that the results derived from the spatial equilibrium model will have meaning. It would not be meaningful to intersect a demand curve estimated in Canadian dollars with a supply curve estimated in U.S. dollars. In converting the U.S. equations to Canadian currency, we follow the procedure used by Schmitz and Bawden who suggested that this problem could be handled either by currency conversion before the equations are estimated or by building a currency converter into the spatial equilibrium model. The former method was chosen for convenience and because currency adjustments during the estimating period were not substantial.

The estimated supply equations for each region and the resulting short and long run supply elasticities are presented in table 2. Substantial differences exist in the nature of supply response among the three regions. The seasonal intercepts indicate that substantial seasonality exists in all three regions, but that there are differences among them. The coefficients and elasticities relating to the hog price, feedgrain, and beef margin variables indicate that during the estimation period, producers in Eastern Canada and the United States were apparently more responsive to a change in hog prices than feed prices or beef margins. However, in confirmation of Kerr's earlier work, Western Canadian production is affected much less by hog prices than by feedgrain availability and the beef margin.

Demand for Consumption and Demand for Storage

Demand for pork in a given period is made up of both demand for consumption and demand for storage stocks. Storage in the hog market aids in smoothing price variations caused by seasonal production and consumption patterns. Because of this function, our demand for storage equations are based on the inventory demand theory of Klein as discussed by Evans. Klein hypothesizes that inventory demand is made up of two components—transactions demand and speculative demand. Transactions demand is dependent upon the level of activity in the market. It implies, in the case of pork, that packing houses hold a given fraction of their current period kill for transactions. This element of storage demand is incorporated into our equations by including the current period slaughter level as a variable.

Speculative demand for inventory is dependent upon stockholders' expectations about future prices and future production and consumption levels. Expectations about future prices and supplies are incorporated in the storage demand equations by including a distributed lag on the variables. Expectations about future production and consumption imply that stockholders recognize the seasonal nature of production and consumption in the pork sector. Thus, we incorporate seasonality in the demand for stock equations through the inclusion of dummy variables on the intercept terms.

Demand for consumption in a given period is dependent upon the current price of pork, the prices of related products, seasonality, and disposable income. Since current prices affect both the consumption and storage demands, these equations were estimated simultaneously using two-stage least squares.

The demand equations include farm level hog prices. Thus, they represent derived demands. This was done so that they would be consistent with the supplies in the spatial equilibrium model. Since the spatial equilibrium model generates prices, it would not be meaningful to intersect a wholesale or retail demand function with a farm supply.

The estimated equations and their mean elasticities, which are presented in tables 3 and 4, infer a number of things about the structure of demand in the two countries.[5] First, the seasonal factor is important in both demand components in both countries. Second, the determinants of demand for consumption in the two countries appear to be similar, although differences exist in the magnitudes of various parameters. Third, while inventory holders do apparently respond to price expectations in all three regions, the relatively higher elasticities associated with current period slaughter and the substantial seasonal variation in inventories imply that seasonality and transactions demand are the more important determinants of inventory levels.

THE MATHEMATICAL PROGRAMMING MODEL

Market Equilibrium in a Single Period and in Successive Periods

Given the market characteristics presented above and considering the trade dependence

[5] The demand for consumption in Canada is estimated for the country as a whole. This is necessary because no data are available on regional consumption. In the mathematical programming model presented below, the Canadian equation is disaggregated for Eastern and Western Canada on the basis of population in each region.

Table 2. Estimated Supply Equations and Resulting Mean Elasticities

			Regression Coefficients (b_i) and Short and Long Run Elasticities (η) (*t*-Statistics in Parentheses)													
			Pk_{t-5}			PF_{t-5}			FS_{t-5}			BPD_{t-5}			QS_{t-1}	
Region	Qtr.	Intercept[b] (m.lb.)	b_1	Short Run η	Long Run η	b_2	Short Run η	Long Run η	b_3	Short Run η	Long Run η	b_4	Short Run η	Long Run η	b_5	R^2
Eastern Canada	I	8.97	1.08	0.22	0.89	—0.09	—0.03	—0.12				— 0.45	—0.002	—0.008	0.75	0.96
			(4.49)			(—0.33)						(— 0.54)			(8.06)	
	II	1.38														
	III	7.28														
	IV	18.78														
Western[a] Canada	I	27.32	0.369	0.10	0.20				1.06	0.19	0.37	— 3.81	—0.02	—0.039	0.49	0.96
			(1.05)						(2.73)			(— 3.01)			(4.96)	
	II	21.90														
	III	3.76														
	IV	27.16														
United States	I	581.6	18.26	0.16	0.43	—0.71	—0.002	—0.008				—16.31	—0.02	—0.054	0.63	0.91
			(3.46)			(—0.15)						(— 1.35)			(5.30)	
	II	490.8														
	III	424.3														
	IV	1047.4														

[a] The Hildreth Lu procedure was used to re-estimate the initial supply equation for Western Canada because it showed a high degree of serial correlation.

[b] Intercept dummies in all three regions are significant at the 0.05 level as measured by F test.

Table 3. Estimated Demand for Consumption Equations and Resulting Mean Elasticities

			Regression Coefficients (b_i) and Elasticities (η) (t-Statistics in Parentheses)								
			PH_t		PP_t		PB_t[a]		Y_t[a]		
Region	Qtr.	Intercept[b] lbs./cap.	b_1	η	b_2	η	b_3	η	b_4	η	R^2
Canada	I	10.080	− 0.2101 (−10.72)	−0.47	0.0367 (3.27)	0.32	0.0025 (0.25)	0.025	1.933 (4.92)	0.33	0.88
	II	9.770									
	III	9.881									
	IV	10.427									
United States	I	12.936	− 0.2080 (−28.41)	−0.37	0.0071 (1.21)	0.05	0.0281 (4.17)	0.17	1.890 (15.67)	0.38	0.98
	II	12.339									
	III	12.609									
	IV	13.717									

[a] There is multicollinearity between the beef price and income variables for both countries.
[b] Intercept dummies in both countries are significant at the 0.05 level as measured by F test.

between the regions, we hypothesize that the North American pork sector behaves as a competitive spatial system which arrives at a market equilibrium through the process described below.

Current production of pork is strictly a function of lagged prices and production. Therefore, production in a given region and quarter is predetermined. Likewise, cold storage stocks available for consumption in a given region and quarter are also predetermined.[6] Equilibrium prices, consumption, and trade flows in a given quarter are thus jointly determined by the interaction of the predetermined supplies with the demands for consumption, demands for stock, and by transfer costs between regions. This describes the same system of equilibrating forces as was presented by Samuelson in analyzing a simple spatial equilibrium system, except that the potential effect of storage in rationing the product over time and thereby smoothing seasonal price variations is also incorporated.

Over successive quarters, market equilibrium is linked recursively in two ways. First, stocks

[6] Initial stocks in quarter t = initial stocks in $t - 1$ plus additions to stocks in $t - 1$ minus reductions in stocks during $t - 1$.

Table 4. Estimated Demand for Stocks Equations and Resulting Mean Elasticities

			Regression Coefficients (b_i) and Elasticities (η) (t-Statistics in Parentheses)					
			PH_t		QS_t		IS_{t-1}	
Region	Qtr.	Intercept[b] (m. lbs.)	b_1	η	b_2	η	b_3	R^2
Eastern Canada	I	0.210	−0.0930 (1.34)	−0.26	0.0685 (2.41)	0.89	0.6175 (3.31)	0.80
	II	− 1.368						
	III	− 6.395						
	IV	− 4.437						
Western Canada	I	1.567	−0.0886 (1.67)	−0.28	0.1026 (5.58)	1.14	0.1493 (1.11)	0.86
	II	1.760						
	III	− 2.978						
	IV	− 1.289						
United States	I	25.133	−4.267 (5.95)	−0.47	0.1084 (6.65)	1.26	0.2519 (2.74)	0.89
	II	25.314						
	III	−67.980						
	IV	−41.721						

[n] Intercept dummies in all three regions are significant at the 0.05 level as measured by F test.

carried over from quarter t influence prices, consumption, and trade in quarter $t + 1$. Second, there is a recursive relationship because of the lagged production response. Assuming (as our supply analysis has shown) the relevant lag is five quarters, market equilibrium in quarter $t + 1$ is related not only to that of quarter t but also to prices observed by producers in $t - 4$.

In an effort to incorporate the complex set of factors discussed above which affect equilibrium in the North American pork sector, and specifically to test the hypothesis that the sector behaves as a spatially competitive market system, a recursive quadratic programming model was constructed for this study. A schematic representation of the model is presented in figure 1. The figure indicates all endogenous and exogenous variables which interact to determine market equilibrium in the three regions.[7] Exogenous variables are set at existing levels and lagged endogenous variables at predicted levels. These are then collapsed into the intercepts of the equations in the quadratic programming model. Quarterly demand for consumption and stocks equations are incorporated directly into the model while the supply equations are used to estimate quarterly production levels. The model determines optimum prices in each region for a given quarter in its primal formulation and the resulting regional consumption, trade and storage levels in its dual. The model is run recursively for successive quarters by setting the exogenous variables at existing levels and feed-

[7] In the context of this model, endogenous refers to the pork sector variables for which a solution value is obtained. Exogenous refers to demand and supply shifters.

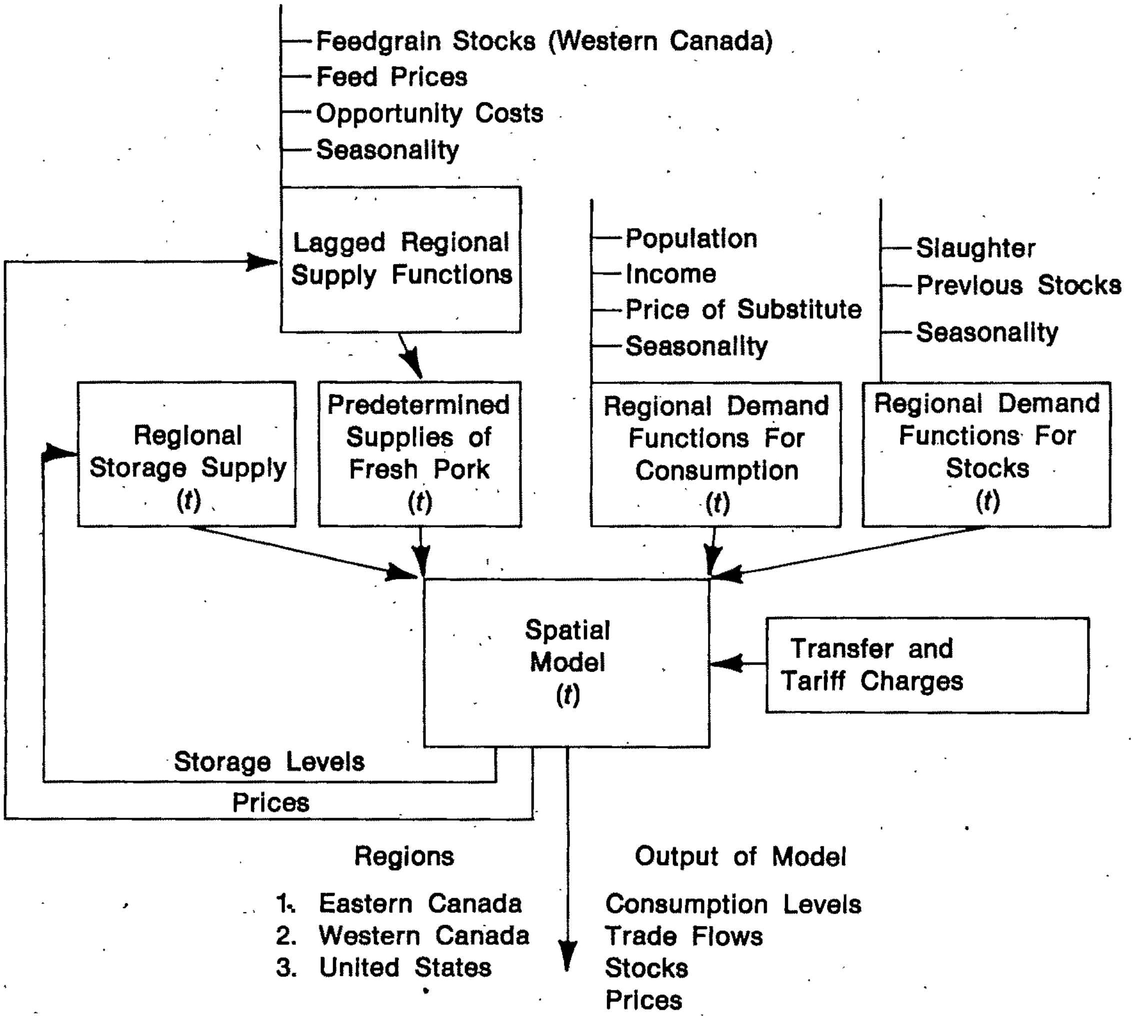

Figure 1. Schematic representation of the model

ing back the predicted endogenous variables into the programming tableau.

The Quadratic Programming Model

The quadratic programming model is based on the price formulation model with fixed regional supplies as specified by Takayama and Judge (1971, chap. 8). However, an adjustment in the Takayama-Judge specification is necessary for the inclusion of storage demand relationships. Therefore, a generalized n region formulation of the model is developed below for a single period, and the programming tableau for the primal programming problem is presented.

From the discussion of demand for consumption, the demand relationship for our problem in the ith region in a given quarter can be represented as

$$(1) \quad QD = a_c - b_{1c}PH_t + b_{2c}PP_t + b_{3c}PB_t + b_{4c}Y_t,$$

where the notation is as defined above.[8] By setting the exogenous variables at predetermined levels for the given period, we arrive at a known demand function for each region of the form,

$$(2) \quad QD = \bar{a}_c - b_cPH_t,$$

where $\bar{a}_c$ includes predetermined values of the exogenous variables. Over all n regions the demand for consumption functions can be generalized in matrix notation to

$$(3) \quad \underset{(n \times 1)}{QD} = \underset{(n \times 1)}{A_c} - \underset{(n \times n)}{\beta_c} \underset{(n \times 1)}{P_y}.$$

P_y represents vectors of regional demand prices.

Similarly, the storage demand relationship for our problem in the ith region and a given quarter can be represented as

$$(4) \quad ID = a_s - b_{1s}PH_t + b_{2s}QS_t + b_{3s}ID_{t-1},$$

and by setting the exogenous variables at predetermined levels for the given period, a known storage demand function for each region which can be represented as

$$(5) \quad ID = \bar{a}_s - b_sPH_t.$$

As with equation (2), equation (5) can be generalized for all n regions to

$$(6) \quad \underset{(n \times 1)}{ID} = \underset{(n \times 1)}{A_s} - \underset{(n \times n)}{\beta_s} \underset{(n \times 1)}{P_y}.$$

P_y represents the same vectors of regional demand prices as in equation (3), since the two equations are estimated simultaneously.

Since the supply of pork in a given quarter is a function of events in previous quarters, the quantity of pork available in the ith region is a fixed quantity. Over all regions, supply quantities can be represented in matrix notation as

$$(7) \quad \underset{(n \times 1)}{QS} = (\overline{QS}_1, \overline{QS}_2, \ldots \overline{QS}_n)'.$$

Similarly, since initial storage stocks in the ith region are predetermined by the previous quarter's carry-over, the fixed storage supplies for n regions can be represented in matrix notation as

$$(8) \quad \underset{(n \times 1)}{IS} = (\overline{IS}_1, \overline{IS}_2, \ldots \overline{IS}_n)'.$$

In addition to these supply and demand relationships the quadratic programming model requires inclusion of a vector of transfer costs. Thus,

$$(9) \quad \underset{(4n^2 \times 1)}{I} = (C, D, E, F)',$$

where $C = (c_{11}, c_{12}, \ldots c_{1n}, c_{21}, \ldots c_{nn})'$, an $n^2 \times 1$ vector of transfer costs for shipping fresh pork from the jth producing region to the ith consuming region;

$D = (d_{11}, d_{12}, \ldots d_{1n}, d_{21}, \ldots d_{nn})'$, an $n^2 \times 1$ vector of transfer costs for shipping fresh pork from the ith producing region to storage in the jth region;

$E = (e_{11}, e_{12}, \ldots e_{1n}, e_{21}, \ldots e_{nn})'$, an $n^2 \times 1$ vector of transfer costs for shipping pork from storage in the jth region to consumption in the ith region;

$F = (f_{11}, f_{12}, \ldots f_{1n}, f_{21}, \ldots f_{nn})'$, an $n^2 \times 1$ vector of transfer costs for shipping pork for storage in the ith region from storage in the jth region.

Using equations (3), (6), (7), (8), and (9), the normative spatial equilibrium model is constructed. Takayama and Judge call the objective function of their model net indirect welfare. They have shown (1964) that this formulation results in a welfare function which is exactly equivalent to the net summed areas under the excess regional demand and supply functions at

[8] Since the demand functions were estimated per capita, all variables in table 3 are multiplied by current population.

equilibrium. In the present situation, the net indirect welfare function which results after integration is adjusted by inclusion of the storage demand activities. This leads to the following primal quadratic programming model:

$$\text{(10)} \qquad \max N.I.W. = A'_c P_y - \tfrac{1}{2} P'_y \beta_c P_y + A'_s P_y - \tfrac{1}{2} P'_y \beta_s P_y - QS' P_x - IS' P_x,$$

subject to $G'P \leqslant C$, $G'P \leqslant D$, $G'P \leqslant E$, $G'P \leqslant F$, and $P_y, P_x \geqslant 0$, where A_c, A_s, β_c, β_s, P_y, QS, and IS are as defined above, $P_x =$ an $n \times 1$ vector of regional supply prices, $P =$ the $2n \times 1$ vector $(P_y, P_x)'$, and $G =$ the standard $2n \times n^2$ transfer matrix $\begin{bmatrix} G_y \\ G_x \end{bmatrix}$ of the form,

$$\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \end{bmatrix}$$

$$\cdots\cdots\cdots\cdots\cdots\cdots$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\;,$$

which insures that the spatial equilibrium conditions are met.[9]

The generalized programming tableau resulting from this primal problem is presented in figure 2. For the present problem, two adjustments were made in the generalized tableau. First, to include consideration of the relatively constant quantity of high quality heavy hams exported by Canada to the U.S., a "dummy" region is included in the model. This region has an associated intercept term equal to actual shipments of this product. It allows the model to fulfill the specialized demand and, at the same time, to respond to price changes with possible trade in lower quality pork between any pair of regions. Second, while the generalized model would imply the necessity of including all the pork transfer activities, interregional trade from storage to storage (in vector F) is considered irrational. Therefore, these rows are deleted.

Comparison with Other Intertemporal Models

The recursive nature of the model makes it somewhat different than the standard intertemporal specification (see Takayama and Judge 1971, chaps. 17–18). The major difference lies in the handling of storage activities. In the standard specification, time periods are separated by known storage costs and, in most cases, some knowledge of minimum inventory levels in the final period is necessary. A model is then formulated which requires the system to optimize over time.

In the present formulation, our concern is to simulate actual market behavior over time and to determine the repercussions that result when the system is shocked by a change in government

[9] In the Takayama-Judge formulation, the problem is finally specified as a primal-dual problem and P_y and P_x are specified with slack activities (i.e., $P_y = \rho_y - w$, $P_x = \rho_x + v$) to insure nonnegative quantities in the dual. This characteristic is omitted here to facilitate the presentation.

Primal Solution Variables			Demand Prices		Supply Prices	
	RHS		P_Y	P_Y	P_X	P_X
Linear Objective Function			A_C'	A_S'	QS'	IS'
Quadratic Objective Function			β_C			
				β_S		
					O	
						O
Linear Constraint Set	C	$\geq$	G_Y		G_X	
	D	$\geq$		G_Y	G_X	
	E	$\geq$	G_Y			G_X
	F	$\geq$		G_Y		G_X

Figure 2. The quadratic programming tableau

policy (see below). Furthermore, like Klein, we recognize that holders of inventory have both speculative and transaction motives in determining their inventory policies. Hence demand for inventories is treated as a separate component of current demand. This would appear to be a correct interpretation since the econometric analysis indicates that inventory demand responds to current prices, but responds in a substantially different manner than the demand for consumption. By interpreting inventory demand as a separate component of current demand, intertemporal price variations in the pork sector can be visualized as arising from a series of short run market equilibria, in which prices are determined based on current supply levels and current levels of exogenous variables in relation to current demands for consumption and storage. This interpretation is reflected in the analysis since each quarter is represented by a separate spatial equilibrium model. Since the model optimizes in each quarter, it requires the explicit consideration of neither storage costs nor minimum inventory levels in the final period. However, since inventory holders do consider storage costs in formulating their inventory policies, these costs are implicitly included in the behavioral demand for storage equations.

VALIDATION OF THE MODEL

The model was validated by running it recursively over a forty-one quarter period from the second quarter of 1963 through the second quarter of 1973. First, all exogenous variables were set at their actual levels in each quarter. Second, storage stocks on hand at the end of the first quarter of 1963 were entered into the initial tableau. For the remaining periods, stocks generated by the model were entered into the successive tableaux. Third, regional supply levels for the first five quarters were predicted with the supply equations using actual prices from the previous five quarters, and entered into the tableaux. For the remaining thirty-six quarters, prices generated by the model were used in the supply equations to predict production levels.

Results of the validation procedure are presented below in two ways. First, actual and generated regional supply, storage levels, and prices are presented in figure 3.[10] Second, Theil U-coefficients for all of the endogenous variables were calculated using the formula presented by

[10] Regional consumption and interregional trade could not be shown graphically since no data exist on actual consumption in Eastern and Western Canada nor on shipments of pork between the two regions.

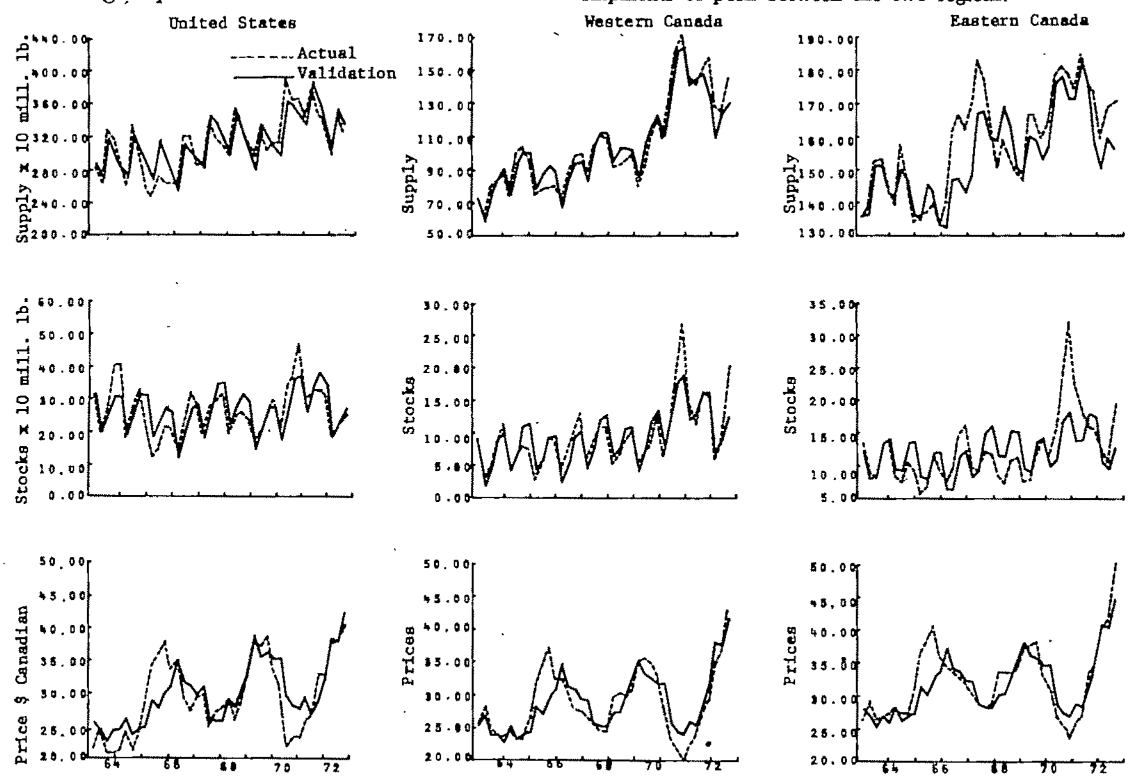

Figure 3. Actual and generated supply, stocks and prices, United States, Western and Eastern Canada, 1963–73.

Naylor. The U-coefficients are constructed so that a value of 0 indicates a perfect simulation of actual variable values by a model while a value of 1 indicates that the model has no simulation ability.

The graphs in figure 3 indicate that the model is able to simulate events in the pork sector very closely over the validation period. Of particular importance is its ability to explain the major cyclical turning points over the period and its ability to reproduce seasonal production and storage fluctuations. The obvious seasonal patterns which exist in these two variables and the lack of seasonal variation in the price variable indicate the importance of storage in smoothing prices when seasonal production and consumption patterns exist. Furthermore, the ability of the model to generate these patterns shows the importance, as Bawden et al. have suggested, of incorporating storage directly into the model.

While the graphical presentation in figure 3 enables us to see the model's ability to explain the turning points, the Theil U-coefficients provide a measure of its goodness-of-fit. Table 5 contains the U-coefficients calculated from the variables in figure 3. These show that the model is quite able to predict actual levels of the variables.

Table 6 contains the inequality coefficients calculated from the consumption and trade variables. Since neither regional consumption nor interprovincial trade data are available for Canada, the validation for these two variables is shown for the entire country. These coefficients indicate that the model is able to explain most of the variation in consumption in the two countries over the validation period. However, its power for explaining actual trade flows is relatively low. International trade in pork rarely amounts to as much as 1% of the total pork produced in North America. Thus, while the model generated trade flows in the proper periods (i.e., exports were generated when Canada was actually exporting and vice versa), the levels of trade generated were sufficiently different from actual levels to result in poor values for the inequality coefficients.

Table 5. U-Coefficients for Regional Pork Supply Storage and Price Variables from Validation, 1963–73

Region	Coefficients for: Supply	Storage	Price
Eastern Canada	0.029	0.146	0.043
Western Canada	0.036	0.100	0.045
United States	0.024	0.084	0.053

Note: The formula for U is $U = \dfrac{\sqrt{1/n\Sigma(P_z - A_z)^2}}{\sqrt{1/n\Sigma P_z^2} + \sqrt{1/n\Sigma A_z^2}}$, where n = number of observations, P_z = predicted value of variable z, and A_z = actual value of variable z.

A POLICY EXPERIMENT

Based on the validation presented above, we conclude that the recursive model has substantial power to explain events in the North American pork sector. This conclusion implies that the econometric estimates embodied in the model reflect the interrelationships which affect short term equilibria in the market and that the model can therefore be used to evaluate the effects that a wide range of policy or structural changes will have on the sector. For example, the authors have conducted an analysis of the effects of several alternative price and income stabilization programs that could be established by the Canadian government (Martin and Zwart).

To illustrate the model's potential usefulness, an experiment was undertaken to evaluate the effects of a change in tariff policy. Prior to 1968, both the U.S. and Canada imposed tariffs of $1.25 per cwt. on pork imported from the other country. Beginning in 1968, these tariffs were reduced in accordance with agreements reached in the Kennedy Round of G.A.T.T. negotiations. The experiment consisted of evaluating the effects that would have occurred if the tariff had been maintained at the pre-1968 level during the period 1968–70. This period is chosen because Canada was a net importer of pork from the U.S. during most of it and our objective is to assess the effects of protecting the Canadian market from U.S. imports. The analysis was conducted by running the model first with the tariff imposed in the transfer cost vector, and subse-

Table 6. U-Coefficients for Canadian and U.S. Pork Consumption and Imports from Validation, 1963–73

Country	Coefficients for: Consumption	Imports
Canada	0.027	0.419
United States	0.031	0.614

quently running it with no tariff imposed.[11] Results generated by the two runs were then compared.

This analysis is somewhat similar to one conducted by Dean and Collins for international trade in oranges except that, while recognizing the potential temporal repercussions of a change in tariff policy when lagged supply response functions exist, Dean and Collins were only able to evaluate the effect of a tariff policy change in a static single period framework. In such a framework, continuation of the tariff would be expected to cause a decrease in Canadian imports of U.S. pork, thereby increasing farm prices in Canada and decreasing them in the U.S.

As would be expected due to the sizes of the markets, our experiment indicates that continuation of the tariff would have had less effect on prices in the U.S. than in the two Canadian regions. Furthermore, the tariff had negligible effects in the first three quarters of 1968. This is because very little trade occurred between the two countries in these quarters. However, price adjustments, which were in accordance with static expectations concerning the effect of the tariff, occurred in the fourth quarter of 1968 and continued through the first quarter of 1970. As expected, the model with the tariff imposed generated somewhat smaller pork imports from the U.S. during these periods. However, Canadian price adjustments took on an opposite pattern for the final three quarters of 1970, i.e., with the continued imposition of the tariff, Canadian prices were lower over this period. The reason for this adjustment is that in response to the higher prices in previous periods, pork production in Canada increased in 1970 while U.S. production decreased slightly.

As a final step in the analysis we present in table 7 the net changes in consumer and producer surplus in the two Canadian regions in each quarter which resulted from continuation of the tariff.[12] The welfare changes are not measured from the objective functions of the model, but rather from the individual demand and supply functions incorporated in the quadratic programming model.[13] The data in table 7 are indicative of the intertemporal welfare costs and benefits to Canadian market participants over the three-year period of maintaining the tariff. As the price and supply adjustments discussed above would imply, the effects in the early periods were positive for both Eastern and Western producers but negative for consumers. However, in the last three quarters of 1970 the opposite occurred. When the results are combined with the realization that in some periods Canada is an exporter of pork to the U.S. (as was the case in 1971), the net effect of a tariff over time, at least at the relatively low level existing prior to 1968, is likely to be negligible in the pork sector.

CONCLUSIONS

Our hypothesis in undertaking this analysis was that the North American pork sector behaves as a spatially competitive market. This hypothesis led to the construction of a competitive spatial equilibrium model. Validation of the model over the ten-year period resulted in optimal price solutions which were remarkably similar to those observed in the market place. Although the U-coefficients used to measure the model's explanatory ability do not provide a rigorous statistical test, their values are suffi-

Table 7. Gains and Losses of Consumer and Producer Surplus in Eastern and Western Canada from Maintenance of the Tariff, 1968–70 (Million C$)

	Eastern Canada		Western Canada	
Quarter	Consumer Surplus	Producer Surplus	Consumer Surplus	Producer Surplus
1968				
1	0	0	0	0
2	—0.22	0.19	—0.08	0.12
3	—0.01	0.01	0	0
4	—2.21	1.81	—0.83	1.11
1969				
1	—2.19	1.81	—0.83	1.13
2	—2.17	1.77	—0.82	1.19
3	0	0.05	0	0.06
4	—2.12	2.03	—0.79	1.16
1970				
1	—1.08	1.57	—0.41	1.12
2	1.86	—0.52	0.70	—0.41
3	2.47	—0.82	0.94	—0.50
4	1.36	—0.30	0.73	—0.75

[11] Actually, the tariffs were gradually reduced over the period to the present level of $.50 per cwt. Since, the actual effect of this level is relatively minor, the experiment removed it completely to show the temporal effects more dramatically.

[12] Dean and Collins (pp. 35–42) provide an excellent discussion of the limitations of measuring consumer and producer surplus. Recognizing these limitations, we present the data in table 7 as being indicative of the true welfare changes.

[13] Formulas for the surplus calculations are contained in Zwart, and Zwart and Martin. Since supplies are fixed in the model, producer surplus in each quarter is identical to total producer revenue.

ciently small to suggest that a competitive equilibrium model can be used to represent the market and, therefore, that the competitive hypothesis can be accepted.

The analysis also underlines the role that storage plays in smoothing prices over time. Our analysis of the supply and demand for consumption in the pork sector showed that substantial seasonal variations exist in these variables. However, the inclusion of storage activities in the model resulted in a storage pattern which tends to offset this seasonality and, therefore, to even out price fluctuations over the year. This confirms the suggestion of Bawden et al. that storage considerations should be included in spatial analyses when storage is an important factor in the market. In addition, the technique used to incorporate storage into the model allows direct consideration of both the transaction and speculative motivations of stockholders.

A final conclusion concerns the ability of the model to show the dynamic impacts of a change in government policy. The tariff policy analysis showed that, because of lagged supply response, the effects of a policy change over time can be substantially different than static analysis would imply. Economists have long recognized the need to construct models with the ability to analyze the impacts of policy changes over time on both the price and quantity variables within a sector and on producer and consumer welfare. For example, King and Bergsten (chap. 1) have recently pointed to the need for this capability in the analysis of domestic and international trade policies. The methodology employed in this study suggests that it may provide a useful approach to such analyses.

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IMPACT OF ALTERNATIVE CLASS I PRICING SYSTEMS ON FLUID MILK PRICES

JOHN B. RILEY and LEO V. BLAKLEY

Changes occurring in the dairy industry necessitate modification of the pricing system for fluid milk. Alterations in the present federal order pricing system, however, will not only affect the level of producer and consumer prices but also have different regional impacts.

Key words: pricing system, fluid milk, spatial equilibrium.

Pricing of milk and dairy products is one of the major policy issues to be resolved during the 1970s. The present system of federal and state orders regulating the marketing and pricing of a major portion of the milk produced in the United States will need considerable modification given the increasing size but decreasing number of dairy farms; the declining production of manufacturing-grade milk; the growth of large, regional cooperatives with centralized control of the milk supply in large areas; the growth and power of supermarket groups as a dominant outlet of packaged milk and milk products; and a changing demand for milk and milk products (Manchester 1971, pp. 54–56). Economic uncertainty in the industry also exists with increased domestic inflation and a new emphasis, perhaps at the expense of the dairy industry (U.S. Congress), on using the total agricultural industry for generating favorable international trade balances.

The present federal order classified pricing system of milk has historically relied upon (*a*) price supports as a market price floor for manufacturing-grade milk and (*b*) a structure of Class I prices for milk used in fluid products based on the market price of manufacturing-grade milk plus a local market, fluid milk price differential. Milk eligible but not used for fluid products is priced generally at the manufacturing-grade, Class II milk price.[1] This system, however, distributes net returns among dairy farmers in a regressive manner (Gruebele), and results in the highest fluid milk prices in markets with the more price elastic demand (Blakley).

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[1] Currently the competitive market price for manufacturing-grade milk is above the support price level. The two prices are generally quite similar.

Given changing market and economic conditions, three alternative pricing systems that could evolve were considered. One was a price structure with a uniform Class I fluid milk price for all markets irrespective of local market conditions (model II). A second reflected the possibility that equity concerns among producers might create a system based on minimum differences in costs of production between markets (model III). A third was governmental policy changes which would eliminate the classified pricing system but maintain a single support price for the commodity (model IV).

To determine the aggregate and regional impact of alternative pricing policies on producer prices and revenues and on consumer fluid milk prices and expenditures, equilibrium conditions were estimated for each of the three proposed alternative pricing systems. Model results were compared with the estimated 1972 spatial equilibrium given the current federal order pricing structure (model I). The effects of a change in the pricing system over time were also considered.

THE MODEL

The Tramel and Seale least-cost spatial equilibrium reactive programming routine was adapted to the fluid milk industry. Data represented sixty-two federal orders in existence January 1, 1972 and 80% of the eligible fluid use milk produced in the U.S. Results were determined for thirty-one study markets, i.e., groups of federal orders, and aggregated into six regional demarcations (fig. 1).

The supply quantity for each market was fixed during any given period but, based on elasticity estimates by Harrington, varied over time in response to changes in blend prices. The linear retail fluid milk demand functions for each market were derived using 1972 market fluid milk consumption quantities and retail prices, and the retail demand elasticity estimates of

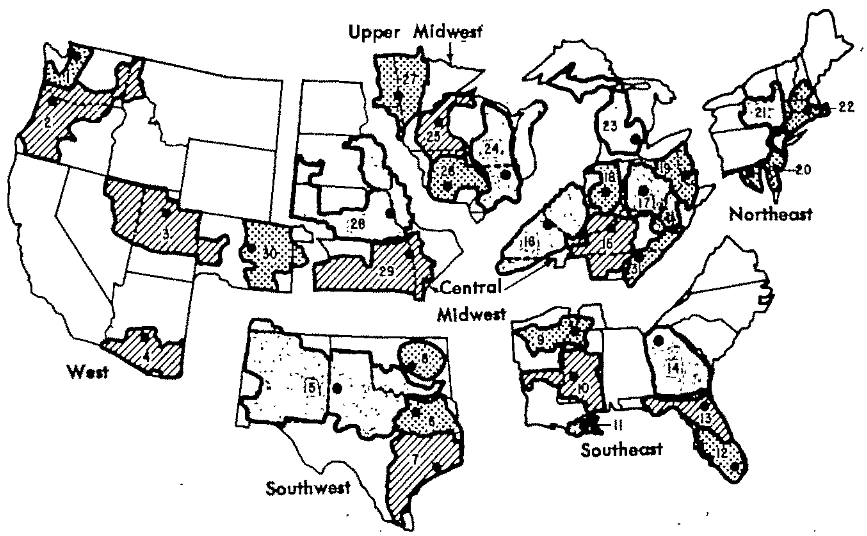

Figure 1. Regions used in study. The solid lines within each region outline the areas of the study market, coded by number. Data for unshaded areas were excluded.

Bullion. Market Class I price equaled the endogenously determined retail price less the costs of processing and retailing the fluid milk sold in that market. The demand and supply elasticities and marketing costs for each market are shown in table 1.

The processing cost function, estimated by Riley, accounted for economics of size in processing fluid milk (Cobia and Babb) and the market structure (Manchester 1968).

$$PE_j = 1.3926 + \frac{0.3844}{PX_j},$$

where

$PE_j =$ processing cost in demand market j (\$ per cwt.),

and

$PX_j =$ fluid milk consumed per federal order within demand market area j (million cwt.).

Market retailing cost, calculated as a percentage of the market retail price, included the costs of moving the fluid product from the processor through the remainder of the marketing channel (table 1).[2]

The weighted market averages of fluid and surplus milk prices, i.e., net blend prices to farmers, differed by no more than the transportation cost between markets. Transportation cost was calculated by

$$T_{ij} = 0.248950 + 0.001583\ M_{ij},$$

where

$T_{ij} =$ transport cost of bulk milk moved from supply market i to demand market j,

$= 0$ for $i = j$ (\$ per cwt.),

and

$M_{ij} =$ one way mileage between supply market i and demand market j.[3]

To account for the seasonal and daily variations in supply and demand (Christ), only 81.3% of the milk supplied in each market was assumed available for fluid use.

THE CURRENT FEDERAL ORDER STRUCTURE

Model I assumed the minimum Class I prices specified for the federal orders in 1972 were effective. Minimum federal order Class I price differentials by study market (fig. 2) were imposed on a Class II price of \$4.93 per cwt. The quantity of milk used as Class I was estimated at 417.9 million cwt. (table 2). Consumption was greatest at 87.4% of local Class I supplies in the Southeast and lowest at 41.7% in the Upper Midwest. Intermarket transfers of fluid

[2] The market retailing cost percentage, estimated from 1972 USDA data, equaled

$$\frac{\text{Market Retail Fluid Milk Price} - \text{Market Farm Fluid Milk Price} - \text{Estimated Market Processing Cost}}{\text{Market Retail Fluid Milk Price}} \times 100.$$

[3] This was estimated from data by Moede. A \$0.20 per cwt. handling charge was added. Surplus milk stayed in the market area with no cost for transporting it to manufactured milk processing facilities.

Table 1. Supply and Demand Elasticities, Example Processing Cost, and Retailing Cost for Fluid Milk by Study Markets

Region	Market Number	Supply Elasticity		Demand Elasticity	Processing Cost[a] ($ per cwt.)	Retailing Cost[b] (%)
		Short Run	Long Run			
Upper Midwest	24	0.19	0.53	—0.22	1.40	39.6
	25	0.19	0.54	—0.22	1.48	33.9
	26	0.05	0.27	—0.30	1.61	34.6
	27	0.19	0.54	—0.22	1.58	42.4
Central Midwest	15	0.11	0.46	—0.48	1.48	38.2
	16	0.05	0.27	—0.30	1.44	39.6
	17	0.05	0.29	—0.35	1.41	36.4
	18	0.05	0.27	—0.35	1.42	34.2
	19	0.05	0.29	—0.35	1.41	37.4
	23	0.05	0.27	—0.22	1.44	32.6
	28	0.11	0.42	—0.30	1.55	34.7
	29	0.11	0.42	—0.30	1.52	41.5
	31	0.20	0.72	—0.60	1.52	37.3
Northeast	20	0.05	0.29	—0.20	1.41	37.1
	21	0.05	0.29	—0.20	1.40	36.8
	22	0.05	0.29	—0.20	1.42	34.5
Southeast	9	0.30	1.02	—0.60	1.57	38.4
	10	0.30	1.02	—0.60	1.52	39.8
	11	0.30	1.02	—0.50	1.49	37.2
	12	0.11	0.67	—0.55	1.46	33.4
	13	0.11	0.67	—0.55	1.46	32.9
	14	0.11	0.67	—0.60	1.42	44.6
Southwest	5	0.30	1.02	—0.50	1.66	36.9
	6	0.30	1.02	—0.50	1.43	37.8
	7	0.30	1.02	—0.50	1.48	33.6
	8	0.30	1.02	—0.30	1.46	36.7
West	1	0.14	0.43	—0.20	1.45	38.9
	2	0.14	0.43	—0.20	1.48	36.1
	3	0.15	0.41	—0.15	1.61	36.7
	4	0.16	1.50	—0.15	1.47	26.8
	30	0.15	0.41	—0.20	1.45	36.7

[a] Market processing cost $(PE_j) = 1.3926 + \frac{0.3844}{PX_j}$ where PX_j in this example is the actual 1972 average fluid milk consumption per federal order in each study market.
[b] Calculated as a percentage of market retail price.

milk totaled 4,483.2 thousand cwt., all moving into the Southeast primarily from the Kentucky and Missouri areas but from as far away as Nebraska, Iowa, and Michigan.

Aggregate consumer expenditures for fluid milk were $5,948.1 million with a retail-equivalent price of $0.61 per half gallon (table 2). The Class I price was highest at $8.33 per cwt. in the Southeast and lowest in the West and Central Midwest at $7.10 and $7.14 per cwt., respectively (table 3). The Upper Midwest region had higher prices than the Central Midwest.[4] As compared with the Northeast, the Upper Midwest had lower Class I prices, but higher retail prices. Blend prices increased as distances from the Upper Midwest region increased. The West was an exception with low prices approaching those in the Upper Midwest.

[4] Including the large Chicago market in the Upper Midwest region heavily influenced regional aggregates. Equilibrium per cwt. Class I prices were $8.20 for Chicago, $6.48 for Minneapolis, $6.71 for Des Moines, and $6.37 for Fargo.

UNIFORM MINIMUM CLASS I PRICES

Model II tested for an equalization of prices among regions with the same minimum Class I price in all markets. An average uniform minimum Class I price of $7.00 per cwt., the simple average of the federal order minimum Class I prices for 1972, resulted in only $0.06 per cwt. lower average Class I price for the aggregate of all regions (table 3). Reductions occurred in the

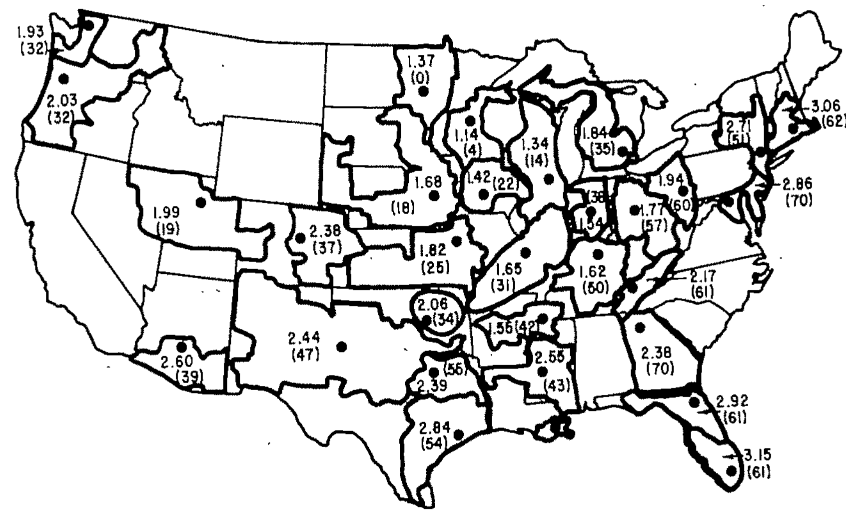

Figure 2. Federal order minimum Class I price differentials in dollars per hundredweight and production cost differentials in cents per hundredweight of milk produced (figures in parenthesis) for each study market.

Central Midwest, Northeast, and Southeast regions. A small increase of $0.03 was shown for the Upper Midwest. Blend price and retail price changes were similar to those for Class I price changes. The extent of equalization of prices among regional markets was small. Directionally, revenue and expenditure changes followed the price changes.[5]

CLASS I PRICE DIFFERENTIALS BASED ON FEED COSTS

Costs of production and technology have perhaps changed enough that the current structure of Class I price differentials no longer accurately reflects cost differences among markets. Model III assumed for each market a basic minimum 1972 Class I price of $6.37 per cwt.[6] plus a market feed cost difference based on the cost of a fixed ration (fig. 2).[7] Lower prices than under

[5] Increasing consumer expenditures would indicate a social loss to consumers while greater producer receipts for a given quantity of milk benefits the dairyman. The actual change in social welfare, however, requires an analysis of producer and consumer surplus.

[6] The $6.37 per cwt. Class I price was the equilibrium price generated in both models I and IV for the Fargo market, the base market for calculating feed cost differentials. The minimum federal order price for the market was $6.30 per cwt. in model I.

[7] Neither the ration of 2.70 tons of 16% protein dairy feed plus 3.15 tons of alfalfa hay nor the level of milk production from this ration, 120 cwt. annually, was assumed to be typical of any region or market. Rather, the ration provided a way to estimate potential feed cost differences which did not reflect current costs of production as determined by historical adjustments to the current milk price structure or the current tech-

Table 2. Supply, Estimated Demand Quantities, and Consumer Expenditures for Fluid Milk under Four Models of Pricing Policies for Class I Milk in Federal Order Markets by Region and Total, 1972

Region	Supply Quantities[a]	Class I Demand Quantities, Models I	II	III	IV	Consumer Fluid Milk Expenditures, Models I	II	III	IV
		Million cwt.				$ million			
Upper Midwest	135.9	56.7	56.6	56.9	57.5	824.6	825.6	815.1	792.4
Central Midwest	207.8	138.5	139.0	139.0	140.2	1,877.8	1,868.6	1,864.6	1,835.8
Northeast	194.2	113.1	113.3	113.5	114.0	1,634.6	1,620.5	1,609.6	1,581.2
Southeast	50.9	44.5	44.8	44.8	45.8	709.8	706.2	706.8	696.6
Southwest	46.6	35.7	35.7	35.7	36.4	510.0	510.0	510.0	498.5
West	49.8	29.4	29.4	29.5	29.6	391.2	390.7	386.6	380.1
Total	685.2	417.9	418.9	419.4	423.4	5,948.1	5,921.7	5,892.8	5,784.7

[a] Adapted from reported data of the U.S. Department of Agriculture. Supply quantities in the base year, 1972, were the same in each market and region for all models.

Table 3. Estimated Class I Prices, Blend Prices, and Farmer Revenues for Milk under Four Models of Pricing Policies for Class I Milk in Federal Order Markets by Region and Total, 1972

Region	Class I Prices, Models				Blend Prices, Models				Total Farm Revenues, Models			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
	$ per cwt.								$ million			
Upper Midwest	7.55	7.58	7.41	7.09	6.02	6.03	5.97	5.84	818.8	820.2	811.4	794.1
Central Midwest	7.14	7.07	7.05	6.85	6.43	6.39	6.37	6.25	1,337.2	1,328.0	1,324.5	1,298.0
Northeast	7.81	7.71	7.64	7.44	6.61	6.55	6.51	6.41	1,282.9	1,272.6	1,265.2	1,245.4
Southeast	8.33	8.21	8.23	7.88	7.69	7.61	7.63	7.34	391.2	387.0	387.9	373.4
Southwest	7.66	7.66	7.66	7.28	7.02	7.02	7.02	6.77	327.0	327.0	327.0	315.2
West	7.10	7.09	6.98	6.81	6.21	6.20	6.14	6.05	309.5	309.1	306.1	301.3
Total	7.55	7.49	7.43	7.19	6.52	6.49	6.45	6.32	4,466.6	4,444.0	4,422.1	4,327.5

the federal order price differential structure resulted, but total consumption increased only 1.5 million cwt.

Consumer prices decreased most in the Northeast followed by the Upper Midwest. Retail prices were unchanged in the Southwest. Blend prices averaged $6.45 per cwt., a decline of $0.07 from the base model. The Northeast had the largest decline of $0.10 per cwt. The decline was about the same in the Central and Upper Midwest regions as in the Southeast.

UNIFORM NOMINAL CLASS I PRICE DIFFERENTIAL

A uniform minimum Class I price differential of $0.20 per cwt. was used as model IV to represent the industry operating with only the support price and no other individual market price restrictions. The $0.20 differential was an allowance to cover any extra costs associated with producing Grade A, fluid, eligible milk rather than Grade B, manufacturing-grade milk in an area such as Wisconsin.

Retail prices, estimated at $0.59 per half gallon, brought a 5.5 million cwt. increase in consumption but a $153.4 million decrease in consumer expenditures for fluid milk. The average Class I price for all regions declined $0.36 per cwt. from model I. Class I price declines were largest for the Upper Midwest, and almost as large for the Southeast, but were lowest for the West.

With farm revenues of $4,327.5 million, blend prices averaged $0.20 per cwt. lower than in model I, but the regional impacts were different than for the Class I prices. Blend prices under model IV declined most in the Southeast ($0.35 per cwt.) followed by the Southwest ($0.25 per cwt.). The decline was somewhat greater in the Northeast than in the two Midwest regions. The Upper and Central Midwest producers, therefore, benefited relative to the other regions by experiencing relatively smaller price declines under this price structure. Regional farm revenues, as in the other models, had the same directional change as occurred in farm blend prices.

Intermarket transfers of fluid milk increased in model IV. Southeast markets imported a total of 5,617 thousand cwt., and a small additional quantity was imported into the Southwest. Exporting regions and quantities exported

nology used in those adjustments. Costs were based on 1968 to 1972 average feed and hay prices.

(in thousand cwt.) were as follows: Central Midwest, 3,125; Northeast, 1,337; Southeast, 1,155; West, 36; and Upper Midwest, 0.

ADJUSTMENTS OVER TIME

Models I and IV represented the two extremes of the situations considered. Adjustments to either higher or lower prices would affect quantities produced which, in turn, could affect regional trends.

Market demand schedules were adjusted to reflect projected population, income, age, racial, and urbanization changes for the years 1973 to 1976 (adapted from Raunikar and Purcell; Raunikar, Purcell, and Elrod). The fixed supply quantity in each market for each year was a function of the previous year's farm blend price and previous year's total Grade A milk production in the market.

The federal order price structure in model I was based on a 1972 Class II price of $4.93 per cwt. Maintaining the minimum federal order Class I price differentials but increasing the Class II price to $5.29 per cwt. in 1973 and by 4% annually to $5.95 in 1976 resulted in increases in the other prices as well as consumer expenditures and producer receipts (table 4). With higher blend prices, production increased at a faster rate than fluid milk consumption, and an increasing total quantity of milk moved into the Class II market. The trend in production was down only in the Northeast.

The 1972–76 Class II prices used for model IV were the same as those used for model I, but the effects were different. Class I prices were slightly higher and blend prices increased as in model I. However, retail prices remained almost constant through 1976 (table 4).

Regional price changes were also different in the two models. With the Class I price differentials of model I, retail and Class I prices were projected to increase in all regions from 1972 to 1976. The change for the Upper Midwest was nominal, however. In model IV, eliminating the Class I price differentials resulted with the passage of time in lower retail and Class I prices in the Upper Midwest, no significant changes for the Central Midwest, and higher prices in the other regions. Consequently, the dispersion in regional prices increased over the study period under the relatively unrestricted prices of model IV. In 1976, the model IV Class I price of $8.19 in the Southeast was $1.61 per cwt. higher than in the Upper Midwest. The largest difference, which was between the Southeast and the West, was only $1.07 in 1972.

SUMMARY AND CONCLUSIONS

Changes in the dairy industry dictate a change in the pricing system for fluid milk. However, changes in the pricing system will affect the spatial equilibrium level of consumer and producer prices, consumer fluid milk expenditures, and producer revenues in both the long and short run. More importantly, any pricing system change will have differential regional impacts.

A structure of minimum Class I milk prices which maintains high consumer prices also maintains relatively high producer prices. With the inelasticity of consumer demand, consumer fluid milk prices and expenditures and producer

Table 4. Estimated Equilibrium Supply and Class I Demand Quantities of Milk, Fluid Milk Retail Prices, Farm Blend Prices, Consumer Fluid Milk Expenditures, and Producer Milk Revenues under Models I and IV, All Federal Order Markets, 1972–76

	Supply Quantities	Class I Demand Quantities	Retail Fluid Milk Prices	Farm Blend Prices	Consumer Fluid Milk Expenditures	Producer Milk Revenues
	---Million cwt.---		---$ per cwt.---		-----$ million-----	
Model I						
1972	685.2	417.9	14.23	6.52	5,948.1	4,466.6
1973	701.8	421.0	14.48	6.73	6,095.0	4,724.6
1974	715.9	423.8	14.73	6.90	6,244.8	4,938.3
1975	728.1	427.3	14.93	7.05	6,381.3	5,734.9
1976	738.9	429.3	15.29	7.27	6,564.7	5,370.2
Model IV						
1972	685.2	423.4	13.66	6.32	5,784.7	4,327.5
1973	699.0	428.1	13.67	6.45	5,852.9	4,508.4
1974	710.6	433.8	13.62	6.51	5,907.6	4,626.5
1975	719.8	437.4	13.77	6.65	6,020.7	4,787.3
1976	728.3	442.9	13.74	6.73	6,086.7	4,904.7

prices and total revenues will fall as the Class I price restrictions are removed. Establishing either a minimum uniform Class I price differential or differentials based on costs of production could have a relatively small impact on price levels.

Different pricing systems have different regional impacts. A new fluid milk pricing system can have the greatest effect on retail prices in one region, but have the most effect on farmer blend prices in another region. The $7.00 per cwt. uniform minimum Class I milk price (a simple average of 1972 federal order minimum prices) would raise prices in the Upper Midwest but decrease prices in all other regions. A change from the present system to pricing milk based on long run minimum differentials in regional costs of production would have the greatest impact in the Northeast U.S.

Continuing the current federal order structure of a basic manufacturing milk price plus Class I price differentials would have little effect on regional price dispersion. In contrast, dispersion of regional prices would increase with a basic manufacturing milk price plus a nominal Class I price differential.

Pricing system changes raise additional questions. The equity of a regional change for producers and consumers as well as the net social gain or loss to society must be considered. What effect will changes in the Class I pricing structure have on the consumption of manufactured milk products? How long will present trends in the industry continue? Estimating regional and aggregate price changes is only a beginning to solving a complex but imminent problem of the dairy industry.

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ESTIMATING A THEORETICAL CONTRACT CURVE BETWEEN VERTICAL STAGES IN THE ILLINOIS GRAIN INDUSTRY

E. DEAN BALDWIN and LOWELL D. HILL

The impact of technological change and the corresponding elevator pricing policy is analyzed for an aggregated corn industry. A set of theoretical and empirical profit and cost functions are estimated and are used to illustrate that the competing sectors are not presently on the presumed contract curve and are not maximizing joint industry profits. The analysis suggests alternative pricing policies and resulting market structure patterns which will simultaneously increase profits for all competing sectors and will minimize total industry costs. Differences in characteristics of the grain industry suggest that alternative sets of market structure patterns and pricing policies may develop.

Key words: structure, profit, cost, corn, elevator pricing policy.

Previous marketing research has emphasized the importance of assembly, distribution, and operating costs on plant location and scale of operation for a specific firm or sector within the marketing channel (Babb and Yu; French; King and Logan; Lytle and Hill; Williamson). In addition, current research within the grain industry has generated separate conclusions for the production sector and the marketing sector, ignoring the interdependency of decisions in these sectors (Kaldenberg; Scott; Welch). This approach not only ignores the more interesting and relevant problems of the grain industry, but may also encourage overinvestment in the industry. Although large capital investments to achieve economies of scale are optimum when grain volume is assumed to be exogenously determined, a different capital allocation is suggested when producer decisions become an explicit variable within the model of marketing firms.

Using models which identify the optimum joint adjustments of the separate, but interdependent, production (Illinois farms) and marketing (Illinois elevators) sectors of the grain industry to changes in the technology of field shelling and artificial drying of corn, this study attempts: (*a*) to adapt existing theory to explain the decision process for allocating grain drying capacity between the farm and elevator sectors; (*b*) to identify the range of elevator drying charges and the corresponding quantities of corn dried at the elevator for a given set of production constraints; (*c*) to determine elevator drying charges that will maximize joint profits or minimize joint costs; and (*d*) to identify the future relationships between the drying, storage, and marketing functions of the two sectors.

THE THEORETICAL MODEL

Given the existence of imperfect competition within the elevator sector, firms are assumed to confront downward sloping demand curves for their services—including drying of grain for farmers.[1] Given adequate time for farmers to adjust drying capacity, variation in the drying charge equates the quantity of drying services demanded with available supply at the elevator and also distributes total profits from drying between the farm and elevator sectors. Because of the existing interdependencies between the two sectors, the profit level and the price-quantity decisions of one sector are influenced by the price-quantity actions of the other. These interdependencies and the alternative economic decisions of each sector can be explained via traditional contract curve analysis which can be generated by deriving equi-profit functions.

Evaluating the choice between drying at the elevator or at the farm requires the following assumptions: (*a*) the total quantity of corn produced in Illinois and its disposition on each farm is determined exogenously and is not affected by the choice of drying methods; (*b*) based upon the expected farm sector responses, firms within the elevator sector vary the drying charge; (*c*)

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[1] Moisture discounts reflect the elevator's price for drying corn sold to the elevator just as the drying charge is the price for drying corn for the farmer.

given farm costs and elevator charges, the farm sector determines when to harvest grain and at what point in the marketing channel to dry and store; (*d*) firms in both sectors select the optimum-size dryer for the volume of corn to be dried; (*e*) the law of diminishing returns and the economies and diseconomies of scale concept imply that the resulting short run average cost and long run average cost curves are U-shaped.

Based on these assumptions, total aggregate farm profits vary with the volume of corn dried at the elevator and are expressed as

$$(1)\quad \pi F = \sum_{j=1}^{m} R_jQ_j - \sum_{j=1}^{m} (AC_jQF_j + OP_jQE_j + OA_jQ_j),$$

where

R = average revenue from sale of grain by farm j,
Q = total bushels of corn produced by farm j,
AC = average cost of drying at farm j,
QF = total bushels dried at farm j,
OP = per unit elevator drying price faced by farm j,
QE = total bushels dried at the elevator by farm j,

and

OA = average cost of farm j related marketing activities (farm havesting capacity costs, farm trucking costs for dry and wet corn, farm storage costs at farm and elevator, farm cost of financing inventories).

The solution to this function generates an aggregated farm profit level which could be represented by point R on figure 1. The elevator drying charge and the corresponding farm costs determine a set of grain drying and storage equipment which permits OQ_1 bushels to be dried at the elevator with the remainder being dried at the farm. Changes in the elevator drying price cannot alter the set of farm equipment in the short run, and all fixed costs of farm drying must be covered.

By assuming that the elevator sector has sufficient equipment to dry and merchandize any quantity of grain, and by assuming that farm drying and marketing costs vary from farm to farm based upon farm characteristics, a reduction in the drying charge below the variable costs of on-farm drying will induce particular sets of farms within the aggregated farm sector to transfer drying from the farm sector to the elevator sector. Indeed, if this change in the drying price just offsets the variable costs of farm drying plus the additional costs of the altered related marketing activities, total farm profits remain unchanged and a second point on the farm equi-profit function is determined. By identifying the range of elevator drying price changes that just offset aggregated farm drying and marketing costs, the volume of grain dried at the elevator is varied within the model to determine the entire farm profit function πF (fig. 1).

A point on a second equi-profit function can be determined by developing a new long run solution with a reduced drying charge. This lower charge results in a new set of farm drying and storage equipment consistent with a new ratio of drying charge to farm costs. Since the drying charge can again be varied to offset any change in farm drying and marketing costs, the entire equi-profit function $\pi F'$ can be determined for this new equilibrium.

To complete the theoretical model, a similar profit function is derived for the elevator sector. Hence, total elevator profits, represented as point S on curve πE of figure 1 are

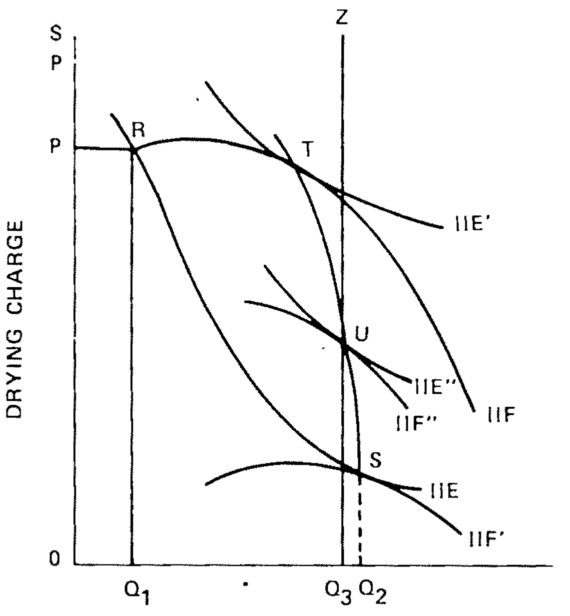

Figure 1. Volume elevator dried, theoretical farm and elevator profit functions, contract curve, and industry function.

$$(2) \quad \pi E = \sum_{i=1}^{n} OQ_i(CR_i - CA_i - OA_i),$$

where

OQ = bushels of grain marketed by elevator i,
CR = average revenue earned by elevator i,
CA = average cost of drying for elevator i,

and

OA = the average cost of related activities for elevator i such as storage, inventory financing, grain handling, etc.

Since the solution to this function establishes a set of drying equipment for the elevator sector, changes in the drying charge cannot alter the elevator plant size. However, changes in the drying price still influence elevator profits by altering the average revenue, the quantity dried, and the volume merchandized by the elevator. By assuming that these elevator facilities can be used more or less intensively and by assuming that the farm sector has sufficient equipment to handle more grain, an increase in the drying price above the variable costs of drying at the farm induces some firms within the farm sector to transfer drying from the elevator to the farm sector. If this increase in the drying price just offsets the increase in the variable cost of elevator-related marketing activities (given that fixed plant size variable costs are inversely related to volume), elevator profits will remain unchanged and a new point on an elevator equi-profit function can be determined. By identifying the range of elevator drying prices that just offset all changes in elevator marketing costs, the entire elevator equi-profit function πE can be determined (fig. 1). A new elevator equi-profit function $\pi E'$ can be derived in a similar fashion by adjusting the drying charge which establishes a new set of elevator drying equipment.

The points of tangency between the farm and elevator equi-profit function identify points along a contract curve. Assuming the combination of drying charge and volume dried at the elevator is represented by point R, changes exist in the drying charge that could move the two sectors to any location on the contract curve between points S and T (fig. 1). The final equilibrium depends upon the existing interdependencies between the two sectors and their respective "economic power."

Since the aggregated farm sector is composed of grain and livestock farms, the latter incur the additional marketing costs of transporting wet grain to the elevator and dry feed stuffs back to the farm. Given the range of sizes and types of farms and elevators, economies of scale of drying exist at both production levels within the industry. Hence, there is an optimum allocation of drying between the farm and elevator sectors that will minimize total costs of drying and marketing for any given combination of farm and elevator types. To identify this point, an industry cost function was defined as

$$(3) \quad \min(Z = \sum_{i=1}^{n} Q_i(ACD_i + AC_i) + \sum_{j=1}^{m} QF_j(ACDF_j + ACF_j),$$

where

Q = total volume of corn dried or marketed by elevator i,
ACD = average cost of drying at elevator i,
AC = average cost of all other marketing activities for elevator i (storing, transporting grain, inventory financing, price risk bearing, etc.)
QF = total volume of corn dried or marketed for farm j,
$ACDF$ = average cost of drying at farm j,

and

ACF = average cost of all other marketing activities (harvesting, storing, transporting, inventory financing, price risk bearing, etc.) for farm j.

Minimization of this function identifies the quantity of corn to be dried at the elevator (Q_3, fig. 1) and at the farm which results in the least cost for farm and elevator firms combined. Since inter-sector transfer of funds were excluded from the objective function, the optimum quantity dried at the elevator is perfectly inelastic with respect to the drying price, and the solution is independent of the specific decision-making variable of each sector. The corresponding drying charge, which will maximize profits ($\pi F''$ and $\pi E''$) for the farm and elevator sectors at the intersection of the contract curve and the cost minimization line, would result in maximum joint returns for the industry (point U, fig. 1).

THE EMPIRICAL MODEL

In order to estimate the theoretical response illustrated by figure 1, a linear programming

model encompassing the marketing activities of two livestock farms, three grain farms, and eight different elevator types was constructed (Baldwin, pp. 18–31). The elevator types dry, store, own, and/or merchandize grain. No other activities such as farm supply distribution and feed milling are considered in this problem. The data for these firms are summarized in table 1 and are derived from a recent survey of Illinois farmers and elevators, engineering data, and from state and federal publications (Illinois Central Railroad; Illinois Cooperative Crop Reporting Service; Kaldenberg; Muller, Wilken, and Kesler; Scott; U.S. Department of Commerce; Welch; Williamson). Since the farm types harvest grain during five different time periods (T_1–T_5), grain is dried at five different beginning moisture levels. Both sectors are permitted to store grain for four different storage periods (t_1–t_4).

The linear programming model encompasses the marketing activities of the five farm and eight elevator types from time of harvest through the first set of marketing outlets. During the above harvesting, drying, and storage periods, the five farms each perform eleven activities (table 2, 1–11). The elevators, on the other hand, each perform six activities (table 2, 12–17).

The three objective functions—profit maximization for the farm and elevator sectors, respectively, and a cost minimization function for the industry are independently solved in this model. Given the elevator drying charge and farm costs, the model is initially solved for the farm profit function. This solution, which is based on activities 1–11 (table 2), permits the farm sector to independently determine the amount of grain that is dried and stored at the farm and elevator and treats the volumes to be harvested, dried, and stored as endogenous variables.

The model is then solved for the elevator objective function. Activities 1–4, 7–9, and 12–17 are used to derive a solution for this sector. The elevator objective function is maximized by forcing a given volume of corn through the marketing channels by virtue of decisions made by the farm sector. Hence, data derived from the farm solution are used as the exogenous variables for the elevator solution. Although data from the farm sector solution sets the upper limits on the quantity that the elevator may dry

Table 1. Summary of Firm Characteristics and Costs Data

Firm Types	Total Acreage Per Farm[a]	Percentage of Harvested Grain Fed to Livestock	Bushels of Grain Merchandised by Each Elevator[b]	Harvesting Cost Per Acre[c]	Trucking Costs from Farm to Elevator or Return[d]	Drying Costs to Dry Corn from 26.4% to 15.5%[e]	Storage Costs for 6-Month Period[f]	Rail Cost for Shipping Grain 990 Miles[g]
				$	$/bu.	$/bu.	$/bu.	$/bu.
Farms								
F1A	120	50		10.00		0.075	0.081	
F2	320	0		9.32		0.045	0.076	
F3	600	0		7.36		0.043	0.063	
F4A	800	150		6.16		0.042	0.060	
F5	1500	0		4.51		0.040	0.055	
Elevators								
E1			700,000		0.017	0.028	0.057	0.23
E2			1,050,000		0.019	0.026	0.057	0.15
E3			2,000,000		0.019	0.025	0.056	0.15
E4			3,000,000		0.020	0.023	0.050	0.15
E5			6,000,000		0.020	0.023	0.053	0.12
E6			9,000,000		0.030	0.023	0.048	0.12
E7			15,000,000		0.030	0.023	0.055	0.12
E8			25,000,000		0.040	0.021	0.050	0.10

[a] Baldwin (p. 38).
[b] Baldwin (p. 56).
[c] Baldwin (p. 46).
[d] Baldwin (p. 47).
[e] Baldwin (pp. 49, 59).
[f] Baldwin (pp. 52, 77).
[g] Baldwin (p. 81).

Table 2. Specific Activities in the Linear Programming Model

Activity Identification Number	Activity Name
1	Harvest corn $(T_1–T_5)$[a]
2	Dry corn at farm $(T_1–T_5)$[a]
3	Store corn at farm $(t_1–t_4)$[b]
4	Truck wet corn to elevator $(T_1–T_5)$[a]
5	Dry corn at elevator $(T_1–T_5)$[a]
6	Store corn at elevator $(t_1–t_4)$[b]
7	Truck dry corn at elevator $(t_1–t_4)$[b]
8	Truck dry corn from elevator to farm $(t_1–t_4)$[b]
9	Feed corn at farm $(t_1–t_4)$[b]
10	Sell corn to elevator $(t_1–t_4)$[b]
11	Buy corn from elevator $(t_1–t_4)$[b]
12	Dry corn $(T_1–T_5)$[a]
13	Store corn for farm $(t_1–t_4)$[b]
14	Store corn for elevator $(t_1–t_4)$[b]
15	Buy corn from farm $(t_1–t_4)$[b]
16	Sell corn to farm and to nonfarm outlets $(t_1–t_4)$[b]
17	Rail corn to nonfarm outlets $(t_1–t_4)$[b]

[a] $T_1–T_5$ refers to harvesting and drying time periods 1–5.
[b] $t_1–t_4$ refers to storing and selling time periods 1–4.

and store for each elevator charge, the elevator sector determines the quantity of drying and storage service it is willing and able to supply. These constraints then permit the farm sector to set the upper limit and the elevator sector to set the lower limit on the volume of grain that the elevator dries and stores for each drying price. Hence, a series of elevator charges can exist in which a deficit or surplus occurs in the respective markets.

The industry objective function is then solved to determine the least industry cost for the performance of activities 1–9, 12–14, and 17 (table 2). Given the level of competition within the grain industry, it would be expected that the two sectors may eventually move toward the industry optimum.

ESTIMATING THE EQUI-PROFIT FUNCTIONS AND THE CONTRACT CURVE

For this model, the alternative farm and elevator equi-profit functions are obtained by utilizing parametric programming techniques on the specified farm and elevator objective functions and right-hand side (constraints) coefficients. By parametrically varying the elevator drying charge coefficient in the farm objective function row, the procedure derives alternative farm profit levels. If the drying charge is continually reduced, farm profits increase and each solution generates a segment of a higher valued equi-profit function.

Additional parametric programming procedures were used to expand the above points into equi-profit functions. By assuming that all fixed costs of the existing farm drying and storage equipment must be met, the farm profit level is maintained through appropriate adjustments in the elevator drying charge. Hence, all increases (decreases) in farm costs are just offset by the appropriate decrease (increase) in the drying price.

A similar procedure specifies a set of specific points representing unique elevator profit levels. Since the volume harvested and the maximum volume of grain dried and stored at elevator is derived from the farm objective function solution, the elevator equi-profit functions are derived by simultaneously changing the drying price, the volume of grain harvested, and the volume of grain dried and stored at the elevator. The farm sector predetermines the harvesting period and the upper limit dried and stored at the elevator. The appropriate coefficients in the constraint vector are revised as each new elevator drying charge is introduced into the elevator objective function row. Although the elevator drying charge is lowered, some of the new points increase elevator profits because of the increase in volume dried and stored at the elevator by the farm sector. Simultaneous parametric programming on the elevator objective function and right-hand side coefficients generates a unique elevator equi-profit function for any specified profit point. These functions are derived by specifying increases (decreases) in elevator drying charges that just negate decreases (increases) in all elevator marketing costs.

RESULTS

Solution of the linear programming model of the farm sector using a drying charge of 1¢ per bushel per point of moisture and total corn production of 850 million bushels identified a point on the farm equi-profit function πF (fig. 2). Profit for the farm sector was maximized at \$742.2 million by harvesting the corn at an average moisture level of 22% and drying 349.7 million bushels at the elevator (fig. 2, point A).[2]

[2] As expressed in the Theoretical Model section, farm profit levels are the net differences between total revenue and all drying and marketing costs. Production activities and costs were not considered in this problem.

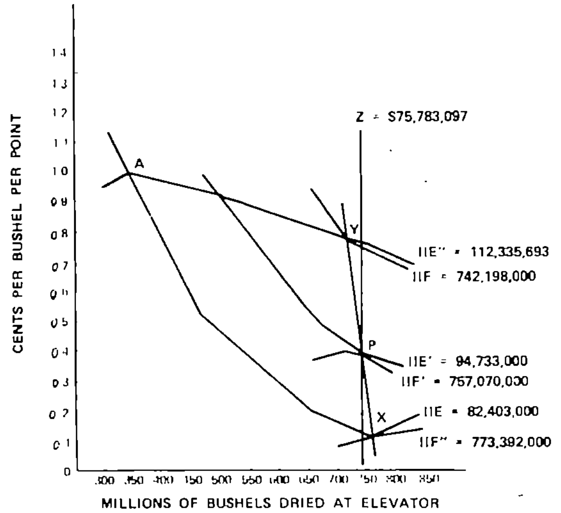

Figure 2. Volume elevator dried, empirical farm and elevator profit function, contract curve, and industry function.

Using the volume of corn delivered by the farm sector and the drying charge of 1.00¢ per bushel per point, the maximum profit for the elevator sector was $82 million. The remainder of the farm and elevator equi-profit functions, πF and πE respectively, were estimated by simultaneously varying the drying charge and the volume dried at the elevator from 300 million bushels to 850 million bushels by 50 million bushel increments (fig. 2 and table 3).

The intersection of these profit functions (πF and πE) indicates that the two sectors are off the contract curve and that lower charges and larger volumes dried at the elevator can increase the profits of one sector without inflicting losses on the other sector. To identify the potential changes in profits for each respective sector, parametric programming was used to vary the drying charge from its present level of 1.00¢ per bushel per point of moisture to a low of 0.11¢. In each case the elevator was assumed to set the drying charge and the farm sector determined the upper limit on the quantity of corn dried by the elevator sector. As the charge was lowered, from 1.00¢ to 0.50¢, the bushels dried at the elevator increased and profits to both sectors increased. At drying charges below 0.50¢, elevator profits decreased. The volume dried at the elevator continued to increase but not enough to compensate for the decrease in average revenue from drying (table 4).

To estimate the location of the contract curve, a number of profit functions were estimated, and profit levels were incrementally increased or decreased until the approximate points of tangency were identified (fig. 2 and table 3). The tangency identified as point X shows a maximum potential profit to the farm sector of $773.4 million, while the combination of a 0.80¢ charge and 715 million bushels elevator dried generated a maximum potential elevator profit of $112 million (fig. 2, point Y). Between points X and Y, numerous combinations of drying charges and volume dried at the elevator lie on the contract curve.

Because there are differences in costs between the farm and elevator sectors, each point on the contract curve not only represents a different allocation of total industry profits but also a different total cost of drying. The total minimum industry cost is determined by solving the industry objective function. This solution, which

Table 3. Required Drying Charge to Maintain Three Potential Farm and Elevator Profit Levels as Volume Dried at the Elevator is Varied

Bushels Dried At Elevator (000,000)	Farm Drying Charge[a]	Elevator Drying Charge[a]
	$\pi F = \$742,198,000$	$\pi E = \$82,403,000$
300	0.98	b
350	1.00	1.000
400	0.98	b
484	b	0.520
500	0.94	b
600	0.86	b
665	b	0.190
700	0.78	b
713	b	0.150
762	b	0.120
800	0.70	b
850	0.66	0.200
	$\pi F' = \$757,070,000$	$\pi E' = \$94,733,000$
350	b	1.700
484	b	1.050
650	0.37	b
665	b	0.500
713	0.40	0.410
750	0.38	b
762	b	0.380
800	0.34	b
845	b	0.320
	$\pi F'' = \$773,392,000$	$\pi E'' = \$112,335,693$
350	b	2.840
484	b	1.800
665	b	0.920
713	0.08	0.775
762	0.11	0.750
845	0.13	0.680

[a] Cents per bushel per point.
[b] Not determined.

Table 4. Actual Profit Levels for the Farm and Elevator Sectors, and Bushels Dried at the Elevator as Drying Charges are Lowered

Charge/Cents/ Bushel Point	Bushels Dried At Elevator[a]	Farm Profits	Elevator Profits
1.00	349,686,397	$742,198,709	$82,403,000
0.90	350,916,771	743,495,416	80,774,000
0.80	350,916,771	744,794,213	b
0.70	479,902,388	746,841,556	86,607,000
0.60	484,111,168	748,913,729	84,285,000
0.50	665,753,239	752,703,679	94,733,000
0.40	713,069,293	757,070,776	94,336,000
0.30	762,686,642	761,950,844	91,198,958
0.11	845,149,937	774,742,524	b

[a] As expressed on pp. 10–12, the bushels dried were derived from the farm profit maximization function and were accepted as exogenous data within the elevator profit maximization function.
[b] Not determined.

limits farm drying to those farms needing the corn for feed and having sufficient volume to be able to dry and store at lower total cost than the elevator costs plus transportation, is represented by Z in figure 2, and requires that 748 million bushels be dried at the elevator. The industry cost minimization function intersects the contract curve at a drying charge of approximately 0.40¢ per bushel per point. Profit functions for the elevator sector, $\pi E'$, and the farm sector, $\pi F'$, reveal that profits for the two sectors are $94.7 million and $757.1 million, respectively.

DIFFERENTIAL EFFECTS BY SIZE AND TYPE OF FIRM

Due to the high fixed cost of drying and storing grain, small cash grain farms that do not have drying and storing equipment on the farm will use elevator drying and storage facilities to condition and store grain if drying charges do not go above the 1.00¢ level (table 5). The small farms which now own equipment will use the elevator services when their present farm equipment becomes obsolete. Results from the model indicate that any reduction in drying or other elevator charges will reinforce this trend. At drying charges of 1.00¢, medium- and large-size cash grain farms will condition and store grain at the farm level. This situation can be reversed if drying charges are lowered below 1.00¢. Hence, the results indicate that at charges of 0.40¢ to 0.80¢, these farms will begin to use elevator services (table 5).

In cash grain areas, economies of scale allow large elevator complexes to have an economic advantage over the smaller firms (table 5). Since these firms merchandize large volumes of grain and since they have relative cost advantages, the results from the model indicate it is to their advantage to induce the farmer to use elevator drying and storage facilities.

Table 5. Marketing Functions Performance Patterns for Elevator Drying Charges

	Dry Corn At Farm	Dry Corn at Elevator[a]			Store Corn At Farm	Store Corn at Elevator[a]		
		$E1$	$E5$	$E8$		$E1$	$E5$	$E8$
1.0¢ Charge[b] (000,000)								
Farm Types[a]								
$F1A$[c]	32.5	16.4		74.6	28.6	5.4		13.5
$F2$	279.4			246.1	244.8			231.8
$F3$	78.0		72.6		68.5		d	
$F4A$[c]	69.0				60.5			
$F5$	49.6				39.1			
0.38¢ Charge[b] (000,000)								
Farm Types[a]								
$F1A$[c]		34.0		34.0		e		29.4
$F2$				534.5				f
$F3$		19.2		126.4		17.7		115.1
$F4A$[c]	69.2				60.6			
$F5$	49.6				39.1			

[a] Farm and elevator classifications are defined in table 2.
[b] Cents per bushel per point.
[c] Livestock farms; all other farm types are cash grain.
[d] Farm sold 68,000,000 bushels to elevator and the elevator stores.
[e] Farm sold 29,000,000 bushels to elevator and the elevator stores.
[f] Farm sold 489,665,451 bushels to elevator and the elevator stores.

Based on the above farm costs and elevator charges, all corn for feed will be dried and stored at the farm level. Furthermore, the results suggest that it is highly unlikely that elevator drying charges can be reduced to a sufficient level to induce livestock farmers to use the elevator drying and storage facilities.

In livestock farming areas, relatively small elevator complexes will serve the farm sector. The costs of trucking corn more than offset the lower costs generated by the larger elevator complexes. These small elevator types will provide those elevator services which benefit the livestock enterprises and will not participate extensively in export trade (table 5).

IMPLICATIONS OF THE RESEARCH

The future structure of the Illinois grain industry depends on many different variables such as the type and size of farms and elevators, the costs of farm drying and storing, trucking costs, elevator drying and storage costs and charges, investment in equipment at farm and elevator, delivery delays at the elevator, and the availability of transportation facilities to move grain out of the elevator. Since these variables comprising the current market structure differ by location and time, the future market structure must vary from one area of the state to another.

The programming models and empirical observation of the industry indicate that the farm and elevator sectors are not currently on a contract curve where joint profits are a maximum. Therefore, an opportunity exists for Pareto-better adjustments within the industry where both sectors can increase total profits through lower costs of operation as they move closer to the contract curve.

There are three rigidities in the industry that partially explain the continued operation at a point off the contract curve. The first is uncertainty and incomplete information as to the response curve of farmers. Elevators have been reluctant to lower drying charges without some assurance of compensating increase in volume. Historically, the drying charge at the majority of elevators has been a 5.00¢ minimum and 1.00¢ per bushel per point (Hill). The industry is currently experimenting with more flexibility in the drying charges and through trial and error may discover the farmer response curve that will move both sectors toward the contract curve. Several Illinois elevators have priced drying services at 0.50¢ per bushel per point during recent years.

The second rigidity is related to the divergence between farmers' actual response curve and the theoretical response curve derived from costs and profit maximization assumptions. Because farmers place a value on noncost factors such as convenience, service, retained ownership of the physical commodity, and the ability to harvest and market grain in a short period of time, their response curve may not permit attainment of the points identified in figure 2.

The third rigidity is the existing age of drying and storage equipment. Prior to the adoption of field shelling and artificial drying equipment, many individual firms within the elevator sector used their facilities only for merchandising grain. Since the farm sector has traditionally performed the storage, drying, price risk bearing, and inventory financing functions, some farms immediately purchased new drying and storage equipment. Hence, maximum joint industry profits as defined by point *P* of figure 2 may not be initially attainable because these investment decisions may cause the individual firms to adjust slowly to the current market pressures (Muller, Wilken, and Kesler).

Movement toward the industry optimum is primarily dependent on action by the elevator sector. This action may take the form of reduced charges to encourage greater volume or improved services to encourage greater volume at existing charges. Individual elevators in many areas of the Cornbelt have initiated action of both types, and it remains to be seen whether these actions will promote sufficient aggregate quantity response from the farm sector to permit the elevator sector to remain on or above its present equi-profit level as the industry moves toward the contract curve and the industry cost minimization quantity.

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WEIGHT LOSS OF FED STEERS DURING MARKETING

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Feeding and marketing practices are related to weight loss of fed steers during marketing. Liveweight and carcass weight losses are higher if feed and water are withheld from steers before slaughter. Packers have incentive to require this practice because the liveweight-cost reduction exceeds the value of the lost weight.

Key words: cattle marketing, shrink.

Weight loss of fed steers during marketing adds to marketing costs. Explanations of variation in weight loss, however, have been incomplete. Previous studies have shown that liveweight loss, or shrink, increases at a decreasing rate with time elapsed during marketing and with shipping distance (Abbenhaus and Penny; Brotherton and Tippets; Henning and Thomas). But these studies also have shown that these two factors explain only part of the variation in liveweight shrink. Carcass weight loss is even less well understood.

This paper reports quantitative estimates of the impacts some factors associated with feeding and marketing practices have on percentage liveweight shrink and on hot carcass weights of fed steers. The results are used to develop guidelines for feeding and marketing decisions and to suggest that a cost-increasing condition of sale is sometimes negotiated on liveweight sales. The results pertain only to fed steers marketed directly from feedlots to packing plants.[1] Weight losses of heifers, of cattle not shipped directly to packing plants, or of carcasses during chilling (i.e., "cooler shrink") were not examined.

MODEL, DATA, AND METHODS OF ANALYSIS

The explanatory factors for percentage liveweight shrink and hot carcass weights considered were weather conditions during the feeding and marketing periods, amount of shelter provided in the feedlot, average daily rate of gain achieved near the end of the feeding period, feedlot weight on the marketing date, shipping distance, a condition of sale requiring that feed and water not be provided during the period immediately before slaughter, and quality and yield grades of carcasses.

Previous studies suggest the nature of the impacts of some of these explanatory factors on weight losses. Percentage liveweight shrink is expected to be less when temperature and other weather conditions are moderate (Brotherton and Tippets; Harston 1959a), when steers are shipped short distances (Abbenhaus and Penny; Henning and Thomas), and when feed and water are provided during the period immediately before slaughter (Harston 1959b). Hot carcass weights have been found unaffected when feed is withheld from cattle for up to forty-eight hours before slaughter (Carr, Allen, and Phar; Kirton, Patterson, and Duganzich). The effect of withholding both feed and water, however, has not been examined, but is expected to reduce hot carcass weights.

Neither amount of shelter provided nor rate of gain have been considered in earlier studies. The amount of shelter may affect weight loss because it affects exercise habits and cleanliness, but the nature of the effect is not clear from a priori analysis. Weight loss is expected to be greater for steers gaining more rapidly before marketing. The impacts on weight losses of feedlot weight, of degree of fatness of the carcass (quality grade), or of ratio of fat to lean in the carcass (yield grade) have been examined, but not well established (Abbenhaus and Penny; Brotherton and Tippets; Henning and Thomas).

Some other factors that are likely to affect weight loss, notably time elapsed during marketing (Brotherton and Tippets; Henning and Thomas) and loading and hauling methods, were

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[1] Shipments from feedlots to packing plants and to other direct outlets (i.e., outlets other than terminal and auction markets) account for most of fed cattle marketings. In 1972, packers procured 81.1% of heifers and steers through direct outlets (U.S. Department of Agriculture).

not explicitly considered in this study. Variation in time elapsed during marketing, however, was closely associated with variations in distance shipped and the condition of sale (i.e., whether feed and water were withheld before slaughter). Loading and hauling methods were not varied.

Data for the analysis were obtained from an experiment conducted at the Iowa State University Allee Experimental Farm near Newell, Iowa during which 585 steers were subjected to different feeding and marketing treatments.

The experiment covered two feeding periods and included three shelter treatments. The 304 steers fed during the first feeding period were marketed in the week of October 1, 1972, after approximately 165 days on feed. The remaining 281 steers were fed during the second feeding period and were marketed in the week of May 27, 1973, after approximately 180 days on feed. Each group was fed in one of sixteen feedlots on the farm. Seven of the feedlots were unsheltered; five were partly sheltered; and four were in a confinement building.[2]

The experiment also included three shipping-distance treatments, and two condition-of-sale (no feed-water and control) treatments. At the end of each feeding period, twelve truckloads of steers were shipped over a three-day period. Steers in each load were taken from each feedlot just before shipment. No more than two steers fed in the same lot were shipped in the same load. One third each of the loads were shipped 40 miles, 80 miles, and 120 miles.[8] The loads shipped each distance were paired, and steers in loads in a pair were slaughtered at the same time. Steers in one (no feed-water) load of each pair were penned at the plant without feed and water for twelve hours before slaughter. Steers in the other (control) load of each pair were shipped from the feedlot twelve hours later, and steers in both the no feed-water and control loads of each pair were slaughtered as soon as the control load arrived at the plant.

Additional detail about the shipment schedule and marketing treatments is presented in table 1. Loads 1–12 were from the first feeding period, and loads 13–24 were from the second. Loads on the same line were slaughtered at the same time. The no feed-water treatment was applied to each odd-numbered load, and the control treatment was applied to each even-numbered load. The first line, for example, shows that load 1 left the farm on Tuesday at 6:00 P.M., and that the twenty-five steers in the load were hauled 120 miles and penned for twelve hours at the plant

[2] The rations fed and the feeding procedures were the same for the different lots and periods except that grain sorghum replaced corn in rations fed some lots, and some lots were fed from self-feeders instead of bunks.

[8] The same size of truck and the same loading and hauling methods were used for each load.

Table 1. Shipment Schedule, Marketing Treatments, and Number of Steers for Each Load

	Shipment Time		Number of Steers Shipped					
			40 Miles		80 Miles		120 Miles	
Paired Loads[a] for Each Feeding Period	No Feed-water	Control	No Feed-water	Control	No Feed-water	Control	No Feed-water	Control
Loads shipped week beginning Oct. 1, 1972:								
1, 2	Tues., 6:00 P.M.	Wed., 6:00 A.M.					25	26
3, 4	Tues., 6:00 P.M.	Wed., 6:00 A.M.			26	25		
5, 6	Wed., 6:00 A.M.	Wed., 6:00 P.M.	26	26				
7, 8	Wed., 6:00 P.M.	Thurs., 6:00 A.M.					25	25
9, 10	Wed., 6:00 P.M.	Thurs., 6:00 A.M.			25	25		
11, 12	Thurs., 6:00 A.M.	Thurs., 6:00 P.M.	25	25				
Loads shipped week beginning May 27, 1973:								
13, 14	Tues., 6:00 P.M.	Wed., 6:00 A.M.					24	24
15, 16	Tues., 6:00 P.M.	Wed., 6:00 A.M.			24	24		
17, 18	Tues., 6:00 P.M.	Wed., 6:00 A.M.	24	24				
19, 20	Wed., 6:00 P.M.	Thurs., 6:00 A.M.					24	22
21, 22	Wed., 6:00 P.M.	Thurs., 6:00 A.M.			24	24		
23, 24	Wed., 6:00 P.M.	Thurs., 6:00 A.M.	23	22				

[a] Paired loads on the same line were slaughtered at the same time. The no feed-water treatment was applied to each odd-numbered load, and the control treatment was applied to each even-numbered load.

without feed and water before slaughter. The line also shows that the twenty-six steers in load 2, the control load paired with load 1, were shipped 120 miles, but left the feedlot twelve hours later so they could be slaughtered immediately on arrival at the plant at the same time that steers in load 1 were slaughtered.

Feeding and marketing treatments, average daily rate of gain during a twenty-eight day period near the end of the feeding period, liveweight at the feedlot before loading, liveweight at the plant before slaughter, hot carcass weight, and the quality and yield grades of the carcass were recorded for each steer. Grading was done by USDA graders.

These data and regression procedures were used to estimate two equations. Dependent and independent variables are defined in table 2. The independent variables initially included in the equation explaining percentage liveweight shrink, Y_1, were $X_1 - X_{10}$ and all two-way interactions involving $X_1 - X_6$. These independent variables plus two-way interactions between X_8 and $X_1 - X_6$ were initially included in the equation explaining hot carcass weight, Y_2.[4]

Table 2. Definitions of Dependent and Independent Variables

Symbol	Definition
Y_1	$= (1 - PW/X_8)$ (100) = percentage liveweight shrink, where PW = liveweight at the slaughter plant.
Y_2	= hot carcass weight.
X_0	= intercept.
X_1	= 1 if fed during first feeding period, −1 otherwise.
X_2	= 1 if fed in unsheltered lot, −1 if fed in confinement building, 0 otherwise.
X_3	= 1 if fed in partly sheltered lot, −1 if fed in confinement building, 0 otherwise.
X_4	= 1 if shipped 40 miles, −1 if shipped 120 miles, 0 otherwise.
X_5	= 1 if shipped 80 miles, −1 if shipped 120 miles, 0 otherwise.
X_6	= 1 if no feed and water before slaughter, −1 otherwise.
X_7	= average daily rate of gain during 28 days near the end of the feeding period.
X_8	= liveweight at the feedlot.
X_9	= quality grade score, ranging from 0 for carcasses grading low Standard to 12 for carcasses grading high Prime.
X_{10}	= yield grade score, ranging from 1.0 for high yielding carcasses to 5.9 for low yielding carcasses.

The statistical model initially specified for both the liveweight-shrink and hot-carcass-weight equations was, in standard matrix notation,

$$Y = XB + U,$$

where the element of the vector of random errors U that corresponds to the jth steer in the ith load, u_{ij}, is given by

$$u_{ij} = v_i + e_{ij},$$

and where v_i is the random effect associated with the ith load, and where e_{ij} is the random effect associated with the jth steer in the ith load. The random errors, v_i and e_{ij}, were assumed to be independently distributed with zero means and variances σ_v^2 and σ_e^2, respectively, where $\sigma_v^2 \geqslant 0$ and $\sigma_e^2 > 0$. This model is of the onefold, nested-error type discussed by Fuller and Battese, where the nests correspond to loads. The covariance structure of the random errors u_{ij} in this model is expressed by

$$\begin{aligned} E(u_{ij}u_{i'j'}) &= \sigma_v^2 + \sigma_e^2, \text{ if } i = i',\ j = j' \\ &= \sigma_v^2 \qquad\quad, \text{ if } i = i',\ j \neq j' \\ &= 0 \qquad\qquad, \text{ if } i \neq i',\ j \neq j'. \end{aligned}$$

An estimation method was selected for each equation. The selection procedure applied to each equation involved two steps. First, the variance components, σ_v^2 and σ_e^2, were estimated by using the "fitting of constants" method.[5] Then, the null hypothesis that $\sigma_v^2 = 0$ was tested. The null hypothesis was rejected for the liveweight-shrink equation, so the estimation method for the onefold, nested-error model that Fuller and Battese suggest was used. Their method involves using the estimates of the variance components to calculate a transformation matrix, premultiplying the original model by the transformation matrix, and then applying ordinary least squares to the transformed model to obtain the generalized least squares estimates. The null hypothesis that $\sigma_v^2 = 0$ was accepted for the hot-carcass-weight equation, so ordinary least squares was applied to the original dependent and independent variables.

The final estimated equations were arrived

[4] Hot carcass weight rather than percentage hot-carcass-weight shrink was used as the dependent variable in this equation because observations on hot carcass weight at the feedlot were not available.

[5] For discussions of the fitting-of-constants method, see Henderson; Searle.

at by deleting from each equation treatments and covariates not significant at the 10% level.[6]

RESULTS

The coefficient estimates and test statistics for the final liveweight-shrink equation are presented in table 3, and those for the final hot-carcass-weight equation are presented in table 4. Percentage liveweight shrink was significantly affected by feeding-period, shelter, shipping-distance and condition-of-sale treatments, by two-way interactions between these treatments, and by feedlot weight. In contrast to percentage liveweight shrink, hot carcass weight was not significantly affected by shipping distance or by two-way interactions, and it was significantly affected by rate of gain and by yield grade.

The negative coefficients of X_1 in tables 3 and 4 indicate that preslaughter liveweights were higher, but that hot carcass weights were lower per pound of liveweight at the feedlot for steers marketed at the end of the first feeding period than for steers marketed at the end of the second feeding period. The higher preslaughter liveweights per pound of feedlot weight (i.e., the lower percentage liveweight shrink) for first-period steers may have been attributable to weather conditions. Weather was cool and wet when the first-period steers were marketed. The second-period steers, on the other hand, were marketed during warm, dry weather. Percentage liveweight shrink was less in cool, wet weather than in warm, dry weather. A major cause of the lower hot carcass weights per pound of feedlot weight for the first-period steers may have been differences in weather conditions during the feeding periods.

The coefficients of the shelter classification variables in the two equations are perhaps surprising. The more shelter provided, the lower is the percentage liveweight shrink, i.e., percentage shrink is highest for no shelter (coefficient of X_2 in table 3), second highest for partial shelter (coefficient of X_3), and lowest for cattle fed in confinement (negative sum of coefficients of X_2 and X_3). Hot carcass weight also increases with the amount of shelter (coefficients of X_2 and X_3 in table 4).

The results concerning the impact of shipping distance on percentage liveweight shrink sup-

Table 3. Liveweight-shrink Equation: Coefficient Estimates and Test Statistics

Variable	F-Ratio	Coefficient Estimate[a]	t-Ratio
Feeding period			
X_1		−0.321	2.987[b]
Shelter	36.34[b]		
X_2		0.273	
X_3		−0.116	
Shipping distance	6.40[b]		
X_4		−0.521	
X_5		0.185	
Condition of sale			
X_6		1.064	9.903[b]
Interactions	2.78[b]		
$X_1 \cdot X_2$		−0.219	
$X_1 \cdot X_3$		0.658	
$X_1 \cdot X_4$		−0.260	
$X_1 \cdot X_5$		−0.064	
$X_1 \cdot X_6$		0.075	
$X_2 \cdot X_4$		0.076	
$X_2 \cdot X_5$		−0.080	
$X_2 \cdot X_6$		0.084	
$X_3 \cdot X_4$		−0.061	
$X_3 \cdot X_5$		0.096	
$X_3 \cdot X_6$		0.161	
$X_4 \cdot X_6$		−0.024	
$X_5 \cdot X_6$		0.203	
Feedlot weight			
X_8		0.002	2.483[b]

Note: The R^2 for the regression of the transformed dependent variable on the transformed independent variables was 0.59.

[a] An example will illustrate the interpretation of these coefficients. Suppose steers weighing 1100 pounds at a feedlot with unsheltered facilities are marketed in the fall, shipped 120 miles, and provided no feed and water before slaughter. The values for the independent variables in the left column are $X_1 = 1$, $X_2 = 0$, $X_3 = 1$, $X_4 = -1$, $X_5 = -1$, $X_6 = 1$, $X_1 \cdot X_2 = 0$, $X_1 \cdot X_3 = 1, \ldots, X_8 = 1100$. The estimated percentage liveweight shrink, then, is the sum of the coefficients of X_1, X_3, X_6, $X_1 \cdot X_3$, $X_1 \cdot X_6$, $X_3 \cdot X_6$, and $X_5 \cdot X_6$, plus 1100 times the coefficient of X_8, which equals 3.571%.

[b] $P < 0.01$.

[6] There was a problem in testing shelter and distance treatments and interactions in the liveweight-shrink equation. To calculate the required F-ratios, reduced models had to be estimated. This required prior estimation of the variance components for the reduced models. Such estimates, however, were different from those for the full model. And when different estimates were used to transform the full and reduced models, the transformed variables in the full and reduced models were different, and the sums of squares used to calculate the F-ratios were not comparable. Therefore, variance components were estimated for the full and all reduced models, a "representative" estimate of each variance component was selected from these estimates, and the same representative estimate of each variance component was used in transforming both the full and reduced models that had to be estimated for each F-test.

Table 4. Hot-Carcass-Weight-Shrink Equation: Coefficient Estimates and Test Statistics

Variable	F-Ratio	Coefficient Estimates	t-Ratio
Intercept			
X_0		-41.638	-4.424^a
Feeding period			
X_1		-2.923	-3.646^a
Shelter	19.17^a		
X_2		-5.062	
X_3		-1.919	
Condition of sale			
X_6		-3.881	4.920^a
Rate of gain			
X_7		-2.312	-3.075^a
Yield grade			
X_{10}		7.777	6.488^a

Note: $R^2 = 0.91$.
[a] $P < 0.01$.

port findings of earlier studies (Abbenhaus and Penny; Henning and Thomas). Shrink increases, but at a decreasing rate as distance increases. Hot carcass weights, however, were not affected by distance shipped.

Withholding feed and water from steers for twelve hours before slaughter had a sharp impact on both percentage liveweight shrink and hot carcass weight. Steers provided no feed and water before slaughter lost an average of 2.128% more liveweight than control steers. The difference was even greater for steers marketed at the end of the first feeding period, fed in unsheltered lots, and shipped short distances. Hot carcass weights of steers provided no feed and water were 7.762 pounds lower than those of control steers. This result and the results of two earlier studies (Carr, Allen, and Phar; Kirton, Patterson, and Duganzich) suggest that withholding feed but providing water to steers before slaughter does not reduce hot carcass weight, but that withholding both feed and water from steers does reduce hot carcass weight.

The coefficients of feedlot weight in the two equations have different meanings. In the liveweight-shrink equation, the positive coefficient indicates that heavier cattle not only lost more liveweight, but also lost a larger percentage of liveweight during marketing than did lighter cattle. In the hot-carcass-weight equation, the coefficient of feedlot weight multiplied by 100 is an average hot-carcass-weight-to-feedlot-weight dressing percentage (63.1%). Two-way interactions between feedlot weight and the classification variables were not significant in the hot-carcass-weight equation. This indicates that the quantitative impacts on hot carcass weight of different feeding-period, shelter, and condition-of-sale treatments were the same for steers with different feedlot weights.

Average rate of gain and yield grade affected hot carcass weight but not percentage liveweight shrink, and quality grade affected neither dependent variable. Hot carcasses of steers gaining more rapidly just before marketing weighed less per pound of feedlot weight than did hot carcasses of steers gaining more slowly. Also, the positive coefficient for yield grade indicates that steers producing higher yielding carcasses (lower yield-grade score) produced smaller carcasses per pound of feedlot weight.

APPLICATIONS

Livestock marketing specialists might use these results to provide cattle feeders with guidelines for selecting feeding practices. For example, feeders investing in feedlot facilities might wish to take into account the impact of shelter on weight losses. The results might also be used to provide feeders and buyers with guidelines for making outlet and pricing decisions. For example, a liveweight bid at outlet k (LB_k) will return more net revenue to a feeder than a carcass weight bid at outlet m (CB_m) if

$$[(1 - \widehat{LS}_k)/(100)X_8]/\widehat{CW}_m > CB_m/LB_k,$$

where $\widehat{LS}_k$ = predicted percentage liveweight shrink at outlet k from the coefficients in table 3, and $\widehat{CW}_m$ = predicted hot carcass weight at outlet m from the coefficients in table 4.[7] A buyer could use guidelines developed from this expression to determine, for example, what carcass weight (liveweight) bid is needed to meet or exceed a competitor's liveweight (carcass weight) bid.

A condition of sale requiring withholding feed and water from steers before slaughter is sometimes negotiated on liveweight sales. The analysis suggests (a) that although this condition of sale increases weight losses and therefore mar-

[7] Other expressions can be used to develop guidelines for comparing two liveweight bids, or two carcass-weight bids. A feeder's net revenue from a liveweight sale at outlet k will be higher than his net revenue from a liveweight sale at outlet m if $(1 - \widehat{LS}_k)/(1 - \widehat{LS}_m) > LB_m/LB_k$. A carcass-weight sale at outlet k will return more net revenue than a carcass-weight sale at outlet m if $\widehat{CW}_k/\widehat{CW}_m > CB_m/CB_k$.

keting costs, it reduces revenue to the packer from the carcass and by-products less than it reduces the cost to the packer of the live animal; (*b*) that because of this, a packer can afford to offer a premium to induce feeders to accept this condition of sale; but (*c*) that the largest premium a packer can offer is less than a feeder would accept provided the feeder was aware of the impact that this condition of sale has on the live-pay weight and, therefore, on his revenue.

Withholding feed and water from steers before slaughter on liveweight sales reduces the packer's revenue by reducing the weight and value of both the carcass[8] and offal[9] components of the live animal. But the cost to the packer of the live animal also is reduced because of the liveweight loss. It is to the packer's advantage, then, to require this condition of sale if the reduction in cost is greater than the reduction in revenue, i.e., if

$$(1) \quad (LP)(PLL)(LW) > (CL)(CP) + (OP)(PLL)(LW),$$

where CW = hot carcass weight in cwt. of steers if feed and water are not withheld, CP = hot carcass value per cwt., LW = live-pay weight in cwt. of steers if feed and water are not withheld, OP = offal value per cwt. of liveweight, LP = liveweight price per cwt., CL = loss of hot carcass weight in cwt. caused by withholding feed and water from steers before slaughter, and PLL = proportion of liveweight lost when feed and water are withheld from steers before slaughter.

The inequality in equation (1) may be rewritten as

$$(2) \quad (LP - OP)/CP > CL/(PLL)(LW).$$

The value of the ratio on the left of the inequality in equation (2) depends on the liveweight, offal, and hot-carcass-weight prices, but can be expected to be only slightly less than the hot-carcass-weight-to-liveweight dressing ratio or approximately 0.6. The term on the right of the inequality in equation (2) is the ratio of the hot-carcass-weight loss to the liveweight loss from holding steers off feed and water. Estimates of PLL and CL can be obtained from tables 3 and 4. With these estimates, the value of the term on the right is less than 0.40 for liveweights greater than 900 pounds. Thus, the inequality in equation (2) can be expected to hold.

Because withholding feed and water from steers before slaughter increases net value to the packer, he can offer a premium if the feeder agrees to this condition of sale. The maximum premium per cwt. of liveweight ($PRMB$) a packer can offer is

$$(3) \quad [(LP - OP)(PLL) - (CP)(CL)(LW)]/(1 - PLL).$$

The premium in equation (3) will be positive if the inequality in equation (2) holds. If the packer is required to pay a smaller premium than this, the condition of sale reduces his live animal cost more than it reduces the value of the carcass and offal he receives.

On the other hand, if a feeder is aware of the impact that this condition of sale has on liveweight shrink, he should not be indifferent about a liveweight bid requiring it and an equal bid that does not require it. Rather, the smallest premium per cwt. of liveweight ($PRMF$) that he should be willing to accept in return for agreeing to withhold feed and water from steers before slaughter is

$$(4) \quad PRMF = [(LP)(PLL) - (FC)/(LW)]/(1 - PLL),$$

where FC is the feeding cost per head avoided by providing no feed for twelve hours before slaughter.

A comparison of equations (3) and (4) suggests that the largest premium a buyer can offer is less than the smallest premium a feeder should be willing to accept to withhold feed and water from steers before slaughter, that is, $PRMF > PRMB$ because it would be expected that $(CL)(CP) + (OP)(PLL)(LW) > FC$. That this condition of sale is sometimes agreed to on liveweight sales indicates that its impacts on weight losses are not well understood by feeders or packers or both.

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[8] The value to the packer will be reduced if the weight of the chilled carcass is reduced, and the weight of the chilled carcass will be reduced unless hot carcasses from steers provided no feed and water before slaughter shrink less in chilling than hot carcasses from steers not receiving this treatment. But some evidence indicates this does not happen; Carr, Allen, and Phar found that hot carcasses from cattle provided no feed before slaughter shrink more in chilling.

[9] Results of one study (Kirton, Patterson, and Duganzich) show that providing no feed to steers before slaughter reduces weights of stomachs, intestines, and lungs.

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EFFECT OF A CONTROLLED PRICE INCREASE ON SCHOOL LUNCH PARTICIPATION: PITTSBURGH 1973

GEORGE A. BRALEY and PAUL E. NELSON, JR.

Direct price elasticities of demand were computed for fully paying students who participated in the National School Lunch Program. For the first time, cross elasticities were computed for recipients of free, hot, Type A lunches. Results are related to earlier findings. Some methodological and program related constraints and implications are presented.

Key words: direct price elasticities, cross elasticities, hot Type A lunch, fully paying students, free lunch recipients, Pittsburgh.

One direct measure of the National School Lunch Program's effectiveness is the degree to which children participate. Program experience has shown that the prices charged for school lunches have a marked effect on the level of student participation.

Historically, most participation studies have been cross-sectional in character, taking observations of numbers of participants from several schools at once. (See Epps; Nicholson; West and Hoppe, which include dates covered.) The tacit assumption is that all participating students may be treated as if they are the same demand curve. Thus, if schools A, B, and C respectively reported prices of 35¢, 25¢, and 20¢, the number of students receiving lunch at each price then would be plotted. Such data plots would provide the basis for a regression fitted to the reported points. The most recent studies (Epps; Nicholson; West and Hoppe) each had over 100 such observations.

These studies have been useful. However, since these regression analyses involve comparisons of behavior patterns of different student populations,[1] a study of the behavior of the same population before and after a substantial price increase provides a useful check on the results from these earlier regressions. If the results are consistent, continued use of the cross-sectional approach will have been supported. In addition, more recent data are more reflective of the inflationary pressures confronting schools today.

In this article we shall (*a*) present direct price elasticities of demand computed from observations made in Pittsburgh, comparing them with results of the studies cited above; (*b*) report (for the first time) cross elasticities between the related changes in lunch price and the numbers of students in the free lunch group; and (*c*) relate certain findings to the question of whether a drop in the number of participants necessarily causes a decline in the amount of Federal support.

PITTSBURGH'S EXPERIENCE

During the 1972–73 school year Pittsburgh maintained sixty-seven public schools, forty-seven elementary and twenty secondary. Of these, nine elementary and all secondary schools provided a hot, Type A Lunch. The residual thirty-eight schools supplied only cold bag lunches for 10¢ apiece and the price did not change during the year. The level of student participation in this cold lunch program was stable throughout the school year. For example, in January (the month prior to the price change for the hot lunch) participation was 68.55%, and in February (the month of the price change) it was 68.52%. These data for cold lunch schools where no price change was made indicate that public schools in Pittsburgh were not substantially affected by exogenous events within the community in the period when the price for hot lunches was increased.

Prior to February 5, 1973 all Type A lunches

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[1] These cross-sectional regressions implicitly have an identity problem, that is, whether the students in each school included in such cross-sectional surveys may be treated as being part of the same demand curve. For a

(except for the free ones) sold for 20¢ each. After this date the average price was 46.67¢. This substantial price increase was due to the decision by Pittsburgh officials to reduce local, tax-based funding of the Type A lunch and to raise the Type A lunch price sufficiently to compensate for the fund withdrawal. This policy change, incidentally, brought Pittsburgh's price in line with most other large urban communities in the Northeast.

There were no changes in eligibility rules for free lunches during the school year and no external factors affecting the number of households eligible.[2] Parents were informed of the price increase prior to its implementation. Eligibility rules for free lunch participation were reiterated and a midyear sign up opportunity was provided, but no effort was made to solicit free lunch recipients beyond that conducted each September.

Two features associated with the dramatic increase in the school lunch price should be noted. First, its very size may have affected participation differently than the same increase made in smaller increments. Second, at the same time as the price was increased, a reduced price lunch was instituted. Because no reduced price program existed before February 5, 1973, when the price was raised for fully paying students, the impact of price on participation could be analyzed only for the fully paying and free lunch categories. Fortunately for study purposes, the reduced price adopted was 20¢, the price all students had been paying before February 5. Subtracting the number of reduced price recipients (934) in February from the paying January population removed from the analysis those students who became part of the reduced price program. The data concerning the remaining students provided an unusual opportunity to observe behavior associated with a price change under controlled circumstances.

DIRECT PRICE ELASTICITIES

The January–February association between prices charged fully paying students in January and February and the corresponding number of lunches served daily was used to compute the direct price elasticities.[3] In January, the price paid was 20¢ and 11,160 paid meals were served. In February, the weighted average price paid was 46.67¢ and 4,153 paid lunches were served.[4] Thus, in February, the price increased 133.4% while the number of Type A meals served decreased by 62.8%. The average daily attendance in February was 4% greater than in January. The equation $Q = (62.4763 - Y)/0.003806$, where Y represents price and Q represents quantity, is depicted by figure 1.[5]

For discussion purposes, four direct price elasticities were computed for points A, B, C, and arc BC. Point C represents the 20¢ price which prevailed at the time that Pittsburgh officials decided to raise the price of the Type A lunch. If Pittsburgh had raised its price by an infinitely small increment, the point elasticity at C would have offered a reasonable projection of the change in the number of students purchasing lunches. With Pittsburgh's large price increase (20.67¢), the impact of price upon participation is more appropriately represented by the elasticity at point A (46.67¢). For comparison with the results of earlier studies, an arc elasticity is superior. Thus, additional elasticities at point B and for the arc BC were also computed.

succinct discussion of identity problems, and some citations of relevant literature, see Waugh.

2 While Pittsburgh like the rest of the nation experienced inflationary pressures, there were no major strikes, acts of God, or similar forces exogenous to the Pittsburgh lunch program which would have substantially affected response to the Type A lunch price increase. In 1972, Pittsburgh's median cash household income was $7,982, with 66.7% of the households falling below $10,000. *Sales Mgt. Survey of Buying Power* (p. D92) reports household cash income distributed as follows: 0–$2,999 (16.7% of all households); $3,000–$4,999 (10.6%); $5,000–$7,999 (22.8%); $8,000–$9,999 (15.6%); $10,000–$14,999 (19.7%), and over $15,000 (14.6%). The total number of households in Pittsburgh proper was $177.4 thousand.

3 The term "fully paying student" can be misleading. Each participating school was reimbursed (16¢) for each lunch purchased by a "fully paying student" by the USDA. Otherwise, the lunch price would have been higher.

4 The schools established a price system in which a student could purchase lunch tickets for a week for $2.00 (40¢ each) or could purchase their lunch on a daily basis for 50¢. The weighted average price was computed using the number of lunches served at 40¢ and 50¢ as weights.

5 We agree with Bryant (1971) that beyond the range of the Pittsburgh observations two very important constraints would make linearity a questionable assumption. "As the full-price rises the partial derivative with respect to the number of free lunches has to fall as the number of free lunches approaches the number of eligible students. . . . At the other end, as the full-price drops, the partial with respect to the quantity of full-price lunches must approach zero unless some nonstudent demand is allowed." It is probable both ends of the curve eventually become asymptotic to their respective axis.

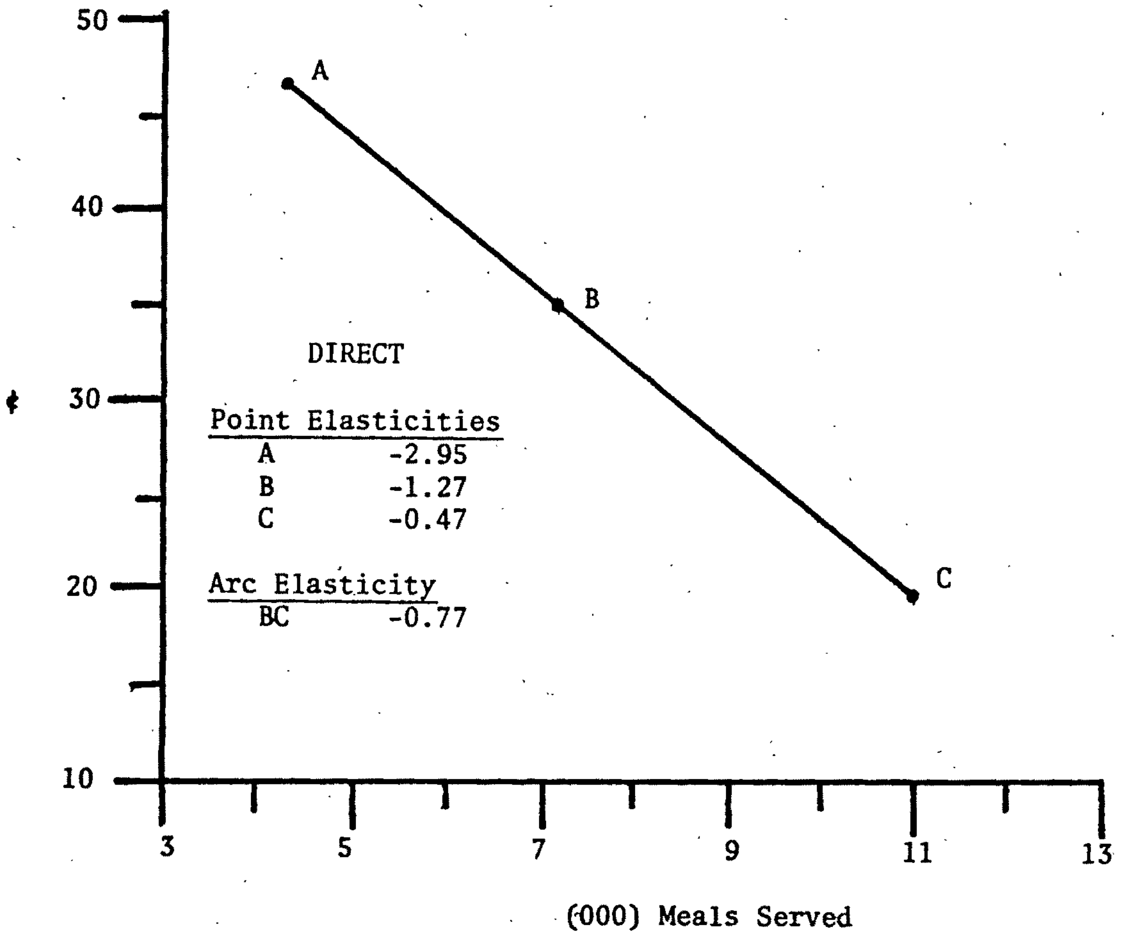

Figure 1. Changes in the number of meals served fully paying students, Pittsburgh, January–February, 1973.

In earlier studies mean elasticities were computed which reflected the heavy weighting of observations falling between 20¢ and 35¢, although each study had some observations falling above 35¢. One report (West and Hoppe) had the most, 39%, but when all studies were considered together, the *B-C* segment (fig. 1) most closely approximated the range in which most observations of the earlier studies fell.

Point *A* is highly elastic, —2.95, and *B* relatively elastic, —1.27 (fig. 1).[6] However, these points are either above or toward the upper end of the 20¢–35¢ range for which the earlier studies had the largest number of their observations. Point *C*, the lowest price level observed, and the arc *BC* both are inelastic, respectively being —0.47 and —0.77. These compare reasonably well with —0.40 (Epps) and —0.50 (Nicholson; West and Hoppe). In summary, direct price elasticities increased substantially when the price rose above 35¢. At point *A* (46.67¢), if a 10% price increase was instituted, a 29.5% decline in the number of fully paying students would be expected.

A second similar set of comparisons was made for January–May. The weekly ticket price and the daily cash price remained unchanged from February 6 through May. However, because the proportion of paying students choosing the cheaper, weekly lunch ticket in May was lower than in February, the weighted average price for fully paying students was 47¢, 0.3¢ higher in May than in February. However, the total number of fully paying students plus free lunch recipients changed very little between February and May, being 12,251 in the former and 12,441 in the latter month.

[6] Obviously, for a given slope, Q/P, elasticities become greater in absolute value as the ratio of price to quantity, P/Q, increases.

The demand association for paying students remained remarkably stable. The analogous elasticities were point A —2.84 (0.11), point B —1.22 (0.05), point C —0.42 (0.05), and arc BC —0.81 (0.04). The figures presented in the parentheses represent the difference in elasticity between January and February 1973, and between January and May 1973.

The evidence of stability is encouraging. However, before considering the current relevance of these elasticities, a comparison with observations from the earlier reports is appropriate. Table 1 presents a comparison of linear-price-participation relationships between Pittsburgh and the other three areas studied. The 1972–73 National School Lunch average price and participation figures were adopted to provide a common basis for comparison. Specifically, rates of participation as related to price (slope of each of the linear regressions reported in the other studies and the Pittsburgh demand function) were transformed so that each of these relationships passed through the point of the national average participation rate (36.83%) at the 38¢ mean national price for 1972–73.

These data reflect the same kind of relationship for the critical range which encompasses the Pittsburgh observations.[7] Comparisons of both price participation rates and the elasticities in the 20¢–35¢ range suggest that cross-sectional data for schools may be treated as if the schools' participating students are on the same demand curve.

CROSS ELASTICITIES

Free Lunch

A 1% change in the price of a Type A lunch causes a change in the number of free, Type A lunches served. Specifically, if given a stipulated percentage increase in the price of Type A

[7] While the cross elasticities would continue to increase above the observed price of 46.67¢, and while theoretically there would be a price at which there would be a 100% participation rate among those eligible, in reality a 100% rate is not likely to be achieved.

At any moment the number of possible free lunch recipients is limited by the community's income eligibility requirements. Persons meeting such requirements do not all participate. All the subsets described may include persons eligible to receive meals without charge, that is, (*a*) some participate as free lunch recipients; (*b*) some choose to pay for their lunches; (*c*) some obtain their lunch from other sources (e.g., home-prepared brown bags, purchased items, gifts from friends, "liberated" items); and (*d*) some eat no lunch. Perhaps the discrepancy is a matter of choice. Some persons may either not know of the program, or they may believe they are ineligible for it.

Of those nonparticipating eligibles, cross elasticities *ceteris paribus* pertain primarily, if not only, to categories or subsets (*b*) and (*e*). It is unlikely, although possible, that the market value of the lunch paid by fully paying students becomes so high that nonparticipating eligibles from categories (*c*) and (*d*) will so recast their utility concept of the lunch that they will choose to participate.

However, changes in food prices also could result in some parents whose children fall in subsets (*c*) and (*e*) becoming sufficiently informed and interested to steer their children into category (*a*). In contrast, the subset (*d*), no lunch, is difficult to identify, let alone encourage participation. Thus, it seems unlikely that the level of free lunch recipient participation will ever achieve its goal of 100% of those eligible.

Table 1. Effects of Price on Paid Lunch Participation in 1972–73

	Reported Slope Coefficient				
	Washington State[a]		ERS[b]	North Carolina[c]	Pittsburgh
	Large	Small			
	—0.812	—0.965	—0.658	—0.700	—0.940
Price (¢)	Average Daily Attendance[d] (%)				
0	83.6	76.2	94.6	91.1	77.3
12.00	68.8	63.8	76.4	74.0	64.5
20.00	59.0	55.5	64.2	62.5	56.0
25.00	52.8	50.3	56.6	55.4	50.7
35.00	40.5	39.9	41.4	41.1	40.0
46.67	26.1	27.8	23.6	24.4	27.6

[a] From West and Hoppe.
[b] From Epps.
[c] From Nicholson.
[d] $X = (Y - C)/b$, where X = the percentage of average daily attendance of students who participated in the school lunch program, Y = the price, C = the price at which participation was zero (the intercept), b = the slope coefficient, and where the coordinates are 38¢ and 0.368% participation for the 1972–73 national program.

lunches, the percentage increase in the number of free lunches served can be estimated.

The full impact of a price increase is not completely identified by determining the numbers of students dropping out of the lunch program.[8] Some will apply either for free or reduced price lunch certification if the latter is available. Small cross elasticities between the numbers of free meal recipients and the prices charged the fully paying students imply that only a small proportion of the "dropouts" will transfer into some free lunch category. The others will either eat no lunch or supply it from other sources (e.g., a brown bag lunch from home, a coke and/or a candy bar, etc.).

Figure 2 depicts the observed association between the price of Type A lunch (Y axis) and the number of free meals served (X axis). For the month preceding February 5, 1973 when the price was 20¢ per lunch, 6,546 free meals were served daily, point A. On February 6, the price increased so that the average price paid was 46.67¢. The average number of free meals served daily from February 6–28 was 8,098, point C. To keep a parallel comparison with the direct price elasticities, the point cross elasticity at B (35¢) was also computed as well as the arc AB (BC in fig. 1).

The cross elasticities for arc AB, and points A, B, C, respectively were 0.23 and 0.18, 0.27, 0.34. Of course, the coefficients became larger as the lunch price increased. However, even with this increase, these coefficients remained small. Their low values indicate there was substantial leakage, that is, most students ceasing to purchase Type A lunches did not transfer into the free

[8] The distinction between expenditure functions for individuals and for a federal program in which they participate, is treated in algebraic detail by Bryant (1974).

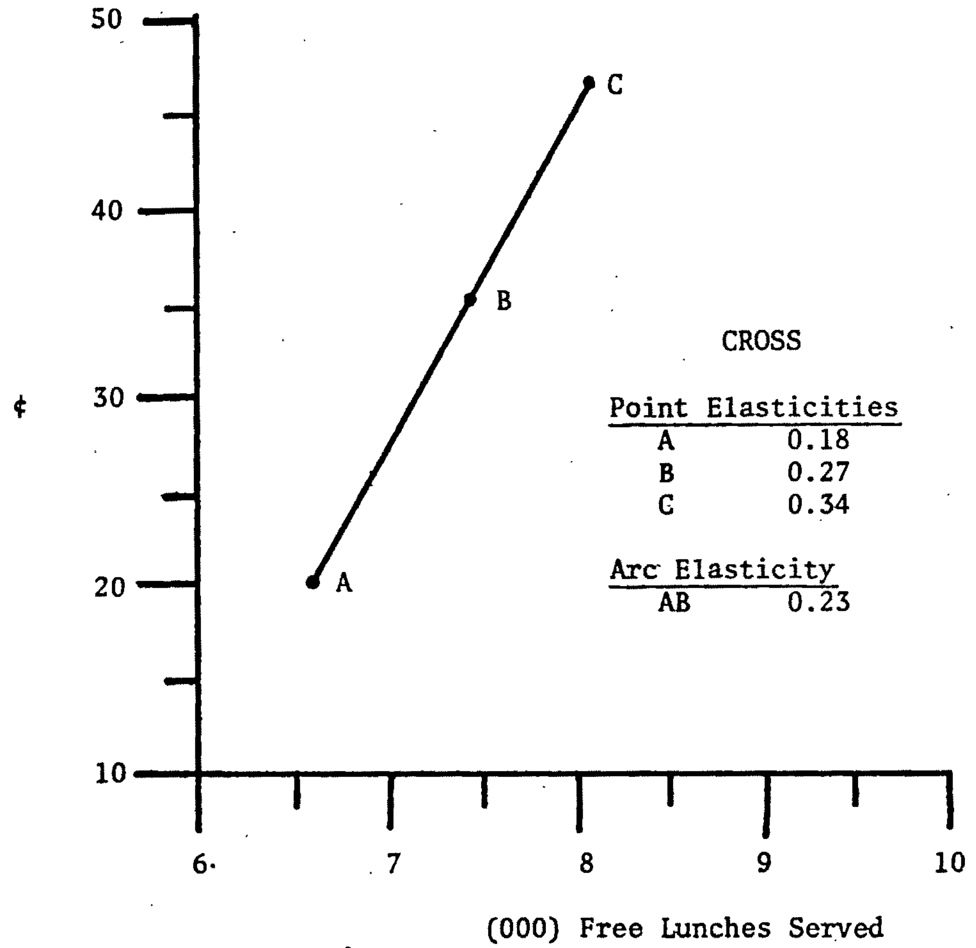

Figure 2. Changes in numbers of free lunches served as prices of lunch increased, Pittsburgh, January–February, 1973.

lunch category. At point C, for every 1% price increase, 0.34% of the students transferred from the fully paying into the free lunch recipient category.

For the May comparison, the January price of 20¢ was used as the initial price, and the May price of 47¢ was used as the new one. In May 1973, schools in Pittsburgh reported serving 8,313 free meals daily. The cross elasticities for points A, B, C, and arc AB (fig. 2) respectively were 0.20 (0.02), 0.30 (0.03), 0.37 (0.03), and 0.25 (0.02). These cross elasticities exhibit a stability similar to that found for the direct price elasticities.

Nonparticipants

We have described participation in free and full pay lunches at the January–February and January–May prices. But what of the nonparticipants? The total of fully paying plus reduced price plus free lunch recipients when substracted from enrollment should yield the number of nonparticipants. However, the closest figure for enrollment is the average daily attendance which fluctuates for various reasons ranging from weather conditions to student illness, etc. Thus, the residual figure representing nonparticipation is not as firm as the figures for participation. However, in view of the low cross elasticities for the free lunch program, we should expect a higher cross elasticity for the nonparticipant category. That is, for each 1% price increase in the lunch there should be a higher coefficient of cross elasticity for those dropping out of the fully paying category than for those entering the free lunch category.

Cross elasticities between the 20¢ initial price and the January–February 46.67¢ price were computed at points analogous to the free lunch category. The respective estimates are 0.72, 0.82, 0.85, and 0.78. The corresponding May results were lower than the January–February findings.[9]

ADDITIONAL FACTORS

Numerous factors must be taken into account when interpreting data such as we have presented. If any substantial changes occur simultaneously with a price change, the total change of course cannot be associated with the change in price. For example, Pittsburgh public schools did not change their price for the Type A lunch between May and October 1973. Yet, the October data show the number of free lunch recipients grew by 1,600. Such growth may have been associated with altered eligibility criteria over the summer, an increased recruitment effort, or the rise in average daily attendance of 11.1%. (However, the numbers of lunch program participants simultaneously rose by 20.6%.)

The change also could be associated with other developments in the economy as a whole. For example, the food-price component of the CPI leaped 6.1% between July and September 1973 (U.S. Department of Labor). Thus, at least some of the increase in the number of free lunches in October may have been associated with the increase in food prices relative to school lunch prices.

SOME IMPLICATIONS FOR THE FEDERAL PROGRAM

The basic consistency of the Pittsburgh data with those of earlier, cross-sectional studies supports the tacit assumption that schools providing data for cross-sectional demand analysis may be treated as if their lunch participants are on the same demand curve. However, in the current inflationary period, the mean elasticities from the earlier studies, weighted by observations in the 20¢–35¢ range may no longer be appropriate for forecasting levels of participation. The Pittsburgh results are most relevant for circumstances in which a Type A lunch price increase would fall within the 35¢–47¢ range. However, the elasticities in any case are estimates, not the true parameters.

The small cross elasticities of the free lunch category suggest that very few students who drop out at the time of a price increase become participants in the free lunch program. The higher cross elasticity of the nonparticipant group implies that many dropping from the program may not be eligible for free lunches. In any case, the high dropout rate accompanied by the moderate rate of increase in the free lunch program does not mean that the level of federal reimbursement will correspondingly decline. For example, by May even though the total number of Type A lunches served declined by 5,280 from January's figure, total federal contributions (commodities plus cash) for hot lunches rose by

[9] These lower May results are more ambiguous. They appear related to the fluctuation in average daily attendance, which for May was lower than for either January or February. We know that the proportion of school lunch participants increased slightly between January and May, despite the dropout of students in May reflected in the decline in the number of students in the residual nonparticipation category.

Table 2. Daily Federal Contribution to Schools for Hot Lunches Served, Pittsburgh 1973

Period	Lunches Served Daily			Federal Contribution ($)[b]			
	Total	Paid	Free & RP[a]	Paid	Free	Reduced	Total
Jan. 1973	18,640	12,094	6,546	1,934.04	3,665.76	—	5,598.80
Feb. 1973	13,185	4,153	9,032	664.48	4,534.88	336.24	5,535.60
May 1973	13,360	4,134	9,226	661.44	4,658.08	388.68	5,648.20

Source: FNS records.
[a] There were no reduced price lunches in January.
[b] Total contribution per meal equaled 16¢ for fully paid lunches, 56¢ for free lunches, and 36¢ for the reduced price lunch.

$49.40 per day or by about $900 per twenty-day, school month (table 2).[10]

Recent changes in legislation and administrative rules have broadened the income range of eligibility for the reduced price lunch program. The high elasticities for the upper portion of the fully paying student's demand curve suggest that a broadened reduced price program could become popular.

In 1972–73, the federal program reimbursed reduced price lunches by an amount equal to the difference between the reduced price charged and the reimbursement for free lunch recipients (36¢). The additional federal reimbursement provided in an expanded reduced price program increases the likelihood that higher prices to paying students will raise federal reimbursement obligations, despite the fact that fewer students would receive the benefits of the program.

[10] For purposes of computing the direct price elasticities for the fully paying students, we had to adjust January figures by excluding 934 students which later in February joined the newly created, reduced price program. However, for the purpose of table 2, we had to recognize that in January, these 934 students were part of the reimbursement (16¢ per student) paid by the federal government for each fully paying student.

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MEASURING FARMERS' TRADE-OFFS BETWEEN EXPECTED INCOME AND FOCUS-LOSS INCOME

J. P. G. WEBSTER and J. O. S. KENNEDY

Farmers' attitudes to risk are viewed within a focus-loss framework. Sets of indifference curves are constructed for five farmers who are willing to forgo expected income for increases in a probabilisticly defined minimum income. Each set of curves is compared with the respective farmer's utility function as derived by the modified von Neumann-Morgenstern method.

Key words: utility analysis, risk, farm planning.

Quantification of farmers' attitudes towards risk is of interest for two reasons. First, such information may enable farm plans to be derived which match the objectives of the farmer better than the traditional profit maximizing plan. Secondly, when used with a planning algorithm, it may help predict more accurately what action the farmer will take in a given situation.

If the aim is to assist farmers in finding a production plan which best meets their objectives, then presenting them with a range of plans is an alternative to presenting them with a programming model which directly incorporates some measure of their attitude toward risk. The range of farm plans could reflect the possible trade-offs among the farmers' several important objectives, thus leaving it to the farmer to make the final decision. However, if the aim is to predict the behavior of farmers, this alternative is not available.

This article describes a method of measuring farmers' attitudes towards the dispersion of farm income and presents the results obtained from applying the method in case studies of five farmers. If certain restrictive assumptions are made, the results from this method may be compared with those obtained by deriving quadratic utility functions in terms of income. A comparison is attempted for the five farmers interviewed. To facilitate manipulation and because of apparent goodness-of-fit which has led to their use by other agricultural economists, quadratic, instead of logarithmic or exponential, utility functions were used for comparison (e.g., Officer and Halter). This is not to ignore their theoretical limitations (Pratt; Tsiang 1972), which are still the subject of debate (Tsiang 1974). Rather, it is shown how the results obtained from our method may be incorporated in a linear programming model for predicting the decision making of farmers.

BACKGROUND TO THE METHOD

Shackle (1961) has hypothesized that decision makers conceive of a simplified model of outcomes resulting from particular decisions. For unique decisions he argues that it is senseless to think the decision maker considers "the entire set of rival and mutually contradictory possible-seeming outcomes" (p. 144). Favorable and unfavorable outcomes result from most actions. The degree of concern for a particular outcome will probably increase as the likelihood of its occurrence decreases. Those extreme outcomes, favorable and unfavorable, which are still thought of as possible and which are of most interest to the decision maker, are termed the focus-gain and the focus-loss of the decision.

In order to arrive at the best decision, the focus-gain and focus-loss are standardized, so that the standardized focus-gain and focus-loss are perfectly possible, i.e., they have zero potential surprise. The set of possible decisions may be ranked by referring to an indifference mapping of standardized focus-gain against standardized focus-loss (Shackle 1961, chap. 20).

Although Shackle's concepts probably lack operational significance, our method of measuring attitudes towards income dispersion incorporates some of his ideas. The problem experienced in applying the "safety-first" linear programming model suggested by Boussard and Petit influenced our formulation of the method. In this

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framework the decision maker is assumed to maximize expected income (E) subject to some specified probability (α) of obtaining a given minimum level of income (F).[1] The criterion suggests that the decision maker has substantial financial commitments each year and that he wants to be reasonably sure that his income will cover them. However, the value of F is not readily determined; a farmer might have difficulty specifying a single invariant value. The approach has also been criticized by Borch (1968, pp. 42–43) on the grounds that strict adherence would require that all plans be rejected where F was not achieved by some infinitesimal amount, regardless of whether they promised very high expected incomes.

In our analysis, we hypothesize that farmers are prepared to trade E for F while maintaining a given level of utility. An interview procedure was devised for estimating (E,F)-indifference curves, which made use of the focus-gain and focus-loss concepts. If (E,F)-indifference curves could be satisfactorily derived, then estimates of the marginal rate of substitution (c) of E for F could be used in conjunction with an objective function (max $[E - cF]$). The marginal rates of substitution on both the production frontier and the indifference curve could be equated and F could be determined endogenously in the model. Allowing F to vary partially circumvents the objection raised by Borch since the probability, α, remains fixed. Only in special cases, to be discussed later, is this problem fully resolved.

THE METHOD FOR DERIVING (E,F)-INDIFFERENCE CURVES

The method entails an interview procedure in which the farmer is directly confronted with a layout describing the possible outcomes of a choice in terms of a focus-gain, a focus-loss and an expected outcome. The layout consists of a sheet of graph paper, with income (I) ruled along the vertical axis and F along the horizontal axis. The range of I is large enough to cover the range of incomes the farmer is likely to experience in practice. I is defined as income before tax. A before-tax definition seemed preferable because the farmer is likely to weigh production decisions in terms of taxable income. We were careful in the interview procedure to run over the taxation regulations, and to remind the farmer throughout the procedure that he was to think of I in terms of income before tax.

The only other equipment used besides the graph was a series of plastic strips of different lengths, with arrows marked at the halfway point. These strips were placed sequentially on the graph, starting with the longest, and aligned parallel to the I axis. The farmer was told that each strip represented a range of possible incomes. For a strip placed at a particular point along the I axis, expected income was marked on the I axis by the arrow halfway along the strip. Other income levels given by the whole of the strip's length were described as possible in the sense that only 10% of the results would fall somewhere below the bottom of the strip, and only 10% of the results would lie somewhere above the top of the strip. To use Shackle's terminology (1958, p. 50), incomes immediately below and above the strip were to be thought of as "unclear" possibilities. The choice of the 10% level of probability was to some extent arbitrary, but probably is a fair approximation of what most farmers would understand as the frequency of an unlikely result. This was the percentage used by Boussard as a result of investigating outcomes of concern for a group of French farmers.

In this way, a strip placed on the graph enabled the farmer to appreciate immediately a range of possible outcomes, which he could relate, however imperfectly, to his own operating experience. After the longest strip on the graph was placed with the arrow marking a prespecified expected income E and after its significance was explained to the farmer, a slightly shorter strip was introduced. The shorter strip represented a smaller dispersion of income possibilities and was positioned alongside the initial strip so that its arrow indicated the same E as the arrow of the initial strip. The farmer was asked which strip represented the more desirable range of income results. If he selected the initial strip, the shorter strip was raised; if he selected the shorter strip, the shorter strip was lowered. The shorter strip was maneuvered until the farmer was indifferent toward the income possibilities represented by the two strips. This procedure was repeated with successively shorter strips until finally an arrow instead of a strip was placed on the graph. This income level was used to represent a fixed salary or the income to be obtained with certainty.

For each strip positioned at a point of indif-

[1] F is equivalent to 'MINI' in the notation of Boussard and Petit.

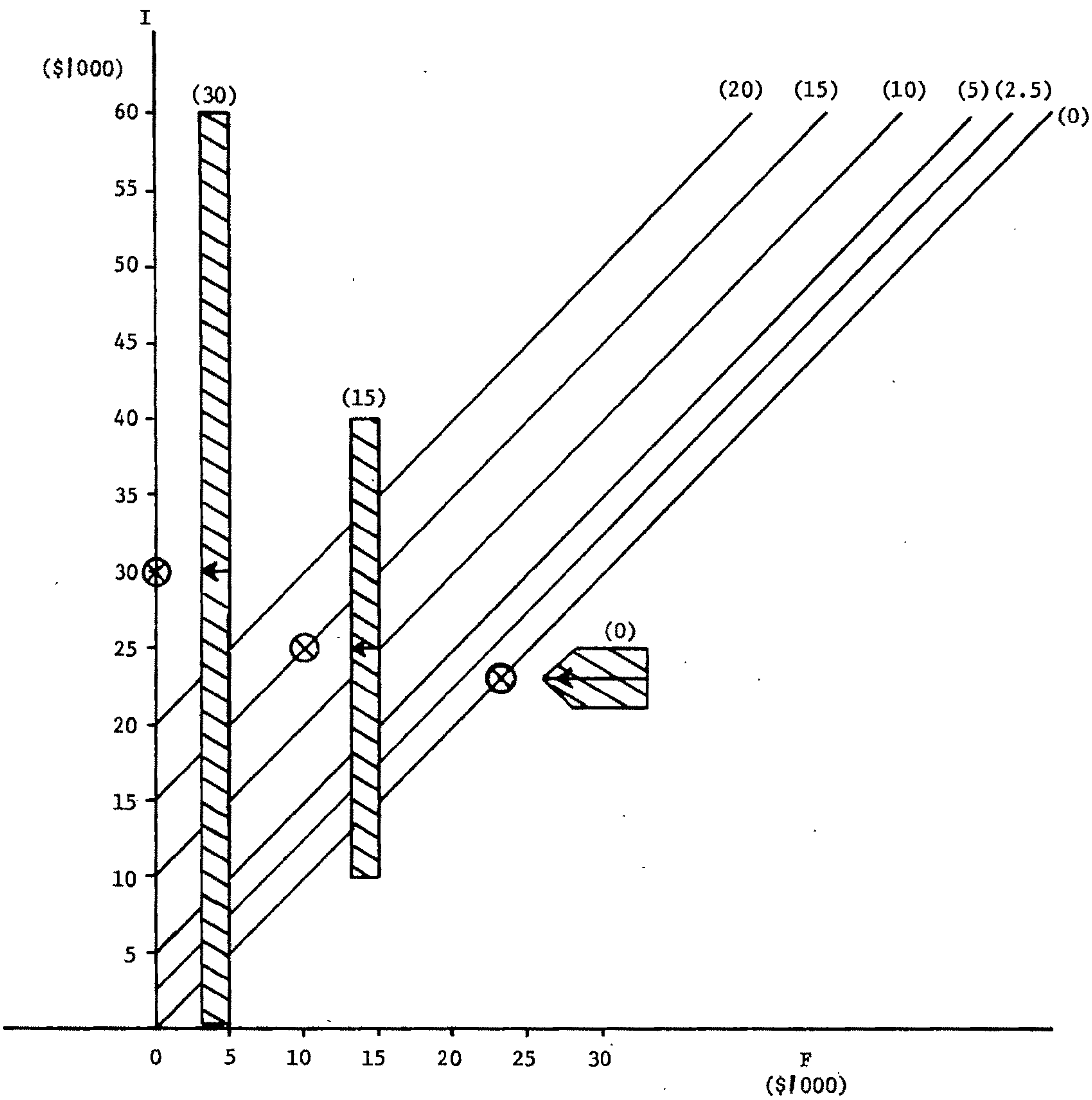

Figure 1. The procedure for plotting (*E*,*F*)-indifference schedules

Note: Halfway points on strips indicate average income. Eight years out of ten, income will lie within the length of the strip. One year out of ten, income will be below the base of the strip, and another year out of ten above the top of the strip. A strip is adjusted vertically until the farmer is indifferent between the set of incomes it represents and the set represented by the reference strip to the left. The 45° lines show where to plot the (*E*,*F*)-indifference point, given *E* and the length of strip.

ference relative to a larger strip, *E* and the focus-loss point *F* were recorded on the graph. Forty-five degree lines, preplotted on the graph for each strip, enabled points to be plotted rapidly (see fig. 1).

The procedure was repeated twice, starting with the largest strip positioned to indicate different starting *E*'s. In this way a series of indifference schedules were derived for the farmer, indicating points of equal utility to the farmer in (*E*,*F*)-space.

RESULTS FROM FIVE FARMERS

Five farmers were interviewed using this procedure.[2] The hand-smoothed schedules for each

[2] The five farmers selected for interview had farms in the vicinity of Tamworth in New South Wales. They all specialized in sheep and grain production. In terms of

farmer are shown in figure 2. Schedule points on the I axis indicate the initial E selected for the largest strip for each of the three schedules. Schedule points on the 45° line from the origin indicate fixed salaries offered to the farmer equivalent to E. Because $E \geqslant F$, there are no feasible points below the 45° line.

Schedules for farmers F1, F2 and F4 are well behaved in the sense of being downward sloping and convex to the origin. The highest schedule for farmer F3 is concave to the origin, indicating increasing utility for F as F increases. However, we were less satisfied with the results which we obtained from this farmer, who seemed to have more difficulty than the other farmers in finding positions of indifference for the strips.

The schedules for farmer F5 are interesting because they are upward sloping for higher values of F. The impression we gained during the interview with farmer F5 was that he disliked the shorter strips not because he did not like higher values of F, but because he preferred the possibility of obtaining a relatively high or low income to a more restricted set of possible results. After all, he explained, that was one reason why he was in farming. The schedules obtained can be explained in terms of increasing followed by decreasing marginal utility for variability of income.

THE INDIFFERENCE SCHEDULES AND QUADRATIC UTILITY FUNCTIONS FOR INCOME

By using the Taylor Series, any utility function $U(I)$ may be expanded about some constant and approximated by an nth degree polynomial, provided $U(I)$ has finite, continuous derivatives up to the nth degree. If derivatives higher than the second are small relative to the corresponding powers of income, $U(I)$ may be approximated by a quadratic. Taking expectations and applying a linear transformation, a quadratic utility function may be written as

$$(1) \qquad E[U(I)] = E + b[E^2 + S^2],$$

where S is the standard deviation of income.

Iso-utility curves based on equation (1) drawn in mean-standard deviation space, denoted (E,S)-space, are concentric circles with center at $E = |1/2b|$, $S = 0$. It is usually assumed that $dU/dE > 0$, which constrains the "rational" arc of the circle to $E < |1/2b|$ and $S \geqslant 0$ (Dillon).

We are interested in determining the shape of (E,F)-indifference curves implied by a quadratic utility function. To do this we have to make an assumption about the relationship between S and F. If we assume that the subjective income distribution is normal, then

$$(2) \qquad F = E - t_a S,$$

where $F < E$ is the level below which the income, I, will fall with probability α, and t_a is the standard normal deviate corresponding to α. Substituting the expression for S from equation (2) in equation (1), $U(I)$ may be derived in implicit form as a second degree polynomial in E and F,

$$(3) \qquad (a+1)E^2 + F^2 - 2EF + (a/b)E - (a/b)U(I) = 0,$$

where $a = t_a^2$.

In those cases where income, I, cannot be assumed to be normally distributed, equation (2) may be replaced by

$$(4) \qquad F = E - \alpha^{-\frac{1}{2}}S,$$

which is based on Tchebycheff's inequality. This inequality holds for any distribution with given E and S (Cramer, pp. 182–83). If equation (4) is used, α is interpreted as an upper bound on the probability that I will fall below F, rather than as the probability, which is the sense in which it is used in equation (2). Use of equation (4) implies $a = 1/\alpha$ in equation (3).

Just as (E,S)-indifference curves may be derived from a quadratic utility function as in equation (1), given equations (2) or (4), (E,F)-indifference curves may also be derived from equation (1). A first restriction put on the (E,S)-indifference curves was that $dU/dE > 0$, which also requires that $dE/dS > 0$ and $E < -1/2b$ for risk aversion ($b < 0$). For (E,F)-indifference curves it also seems reasonable that for risk aversion $dE/dF < 0$. From equation (3), the slope of the (E,F)-schedules is

$$(5) \qquad dE/dF = (E - F)/[(a+1)E - F + a/2b],$$

for

$$(6) \qquad dE/dF < 0, E < (F - a/2b)/(a+1).$$

The shape of (E,F)-indifference schedules for

its size, each farm belonged to one of the three representative farm models for the aggregate programming model of Australian agriculture under construction at the University of New England.

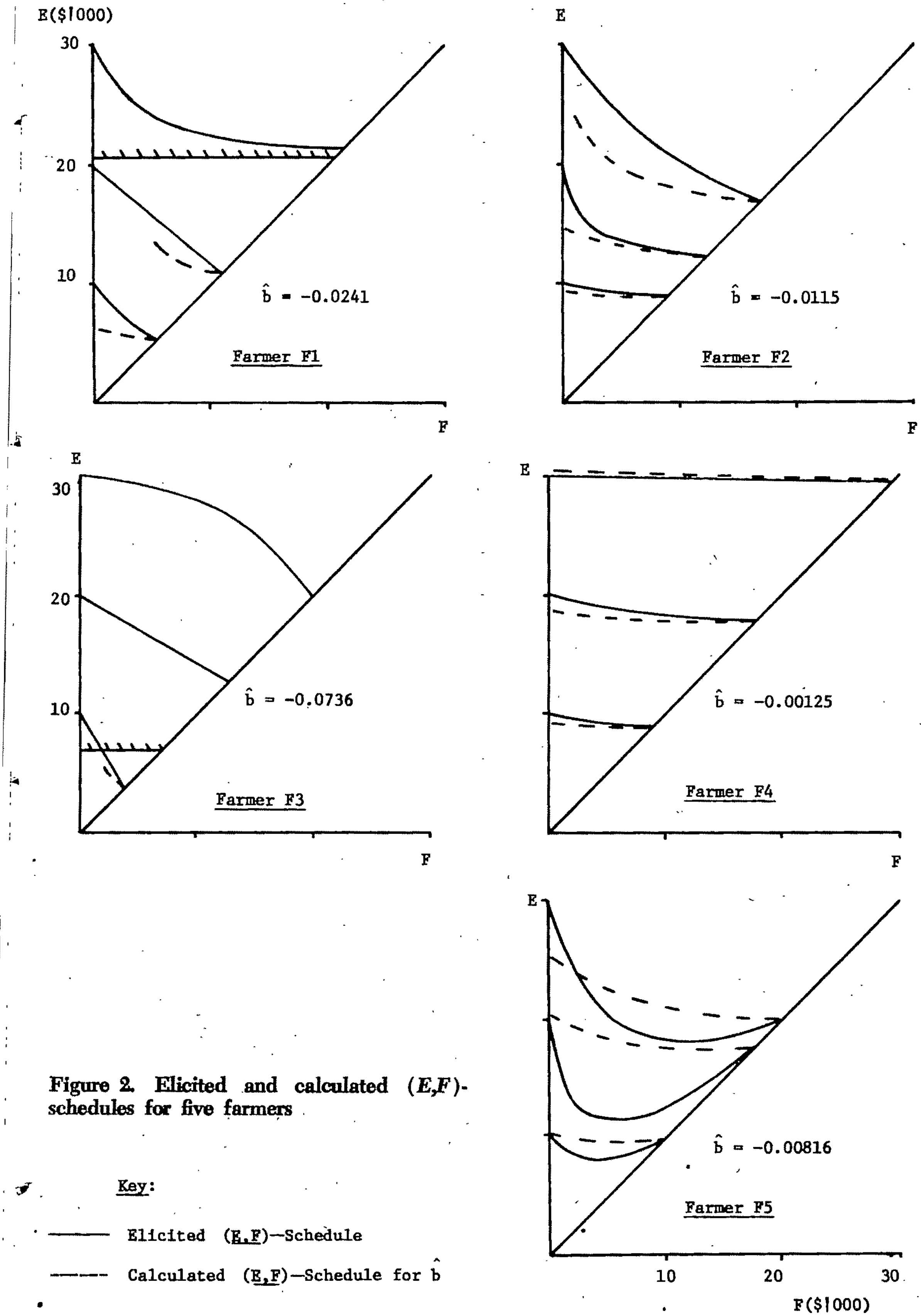

Figure 2. Elicited and calculated (E,F)-schedules for five farmers

Key:

——— Elicited $(\underline{E},\underline{F})$—Schedule

- - - - Calculated $(\underline{E},\underline{F})$—Schedule for $\hat{b}$

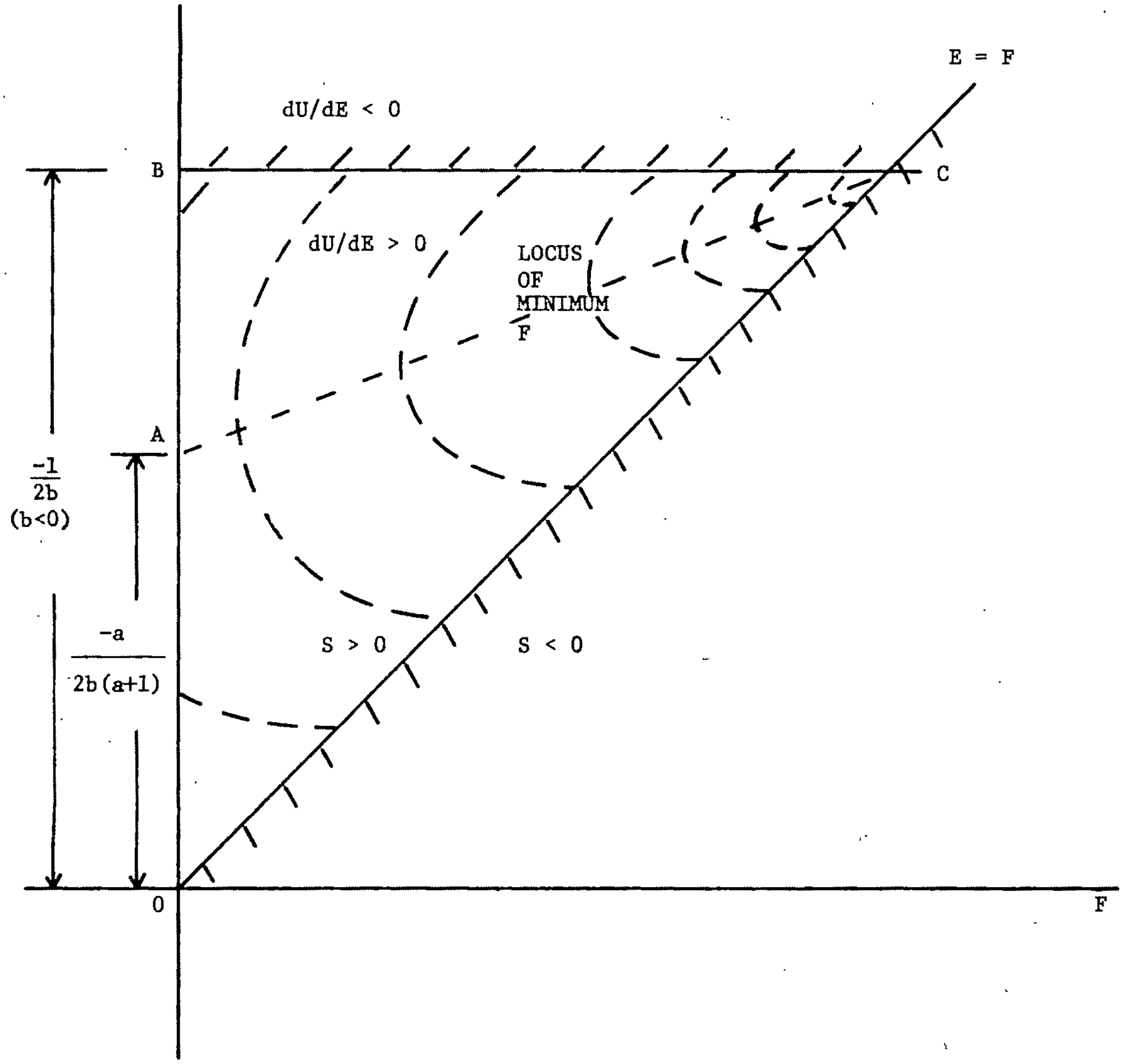

Figure 3. General Form of (E,F)-indifference schedules derived from Quadratic Utility Function.

the quadratic utility function assuming normality is shown in figure 3. Space to the left of the 45° line caters for $S > 0$. Space below the line $E = |1/2b|$ caters for $dU/dE > 0$, and below the line $E = (F - a/2b)/(a+1)$ (AC in fig. 3) for $dE/dF < 0$. The "rational" area for (E,F)-indifference schedules is therefore the triangle ACO.

AN EMPIRICAL COMPARISON

During the interview with each of the five farmers, data were obtained for estimating the farmer's utility function for income by establishing points in (U,I)-space using the questioning procedure involved in the modified von Neumann-Morgenstern method as described in Makeham, Halter, and Dillon. The points were derived by determining for the farmer an income which would give him the same satisfaction as a gamble in which he had a 50% chance of receiving a specified higher income. As with the (E,F)-procedure, it was stressed that the figures were to represent before-tax income. Quadratic equations were subsequently fitted to the points derived and are shown in table 1. Polynomials up to the fifth degree were also fitted but showed little improvement in terms of corrected R^2. Coefficients of I^2 were significant at the 5% level, except for the utility function for farmer F4. The function for farmer 4 closely approximates a straight line.

Given b from the farmer's quadratic utility,

Table 1. Fitted Quadratic Utility Functions

	Subject				
	F1	F2	F3	F4	F5
$\hat{b}$[a]	−0.0241	−0.0115	−0.0736	−0.00125	−0.00816
Corrected R^2	0.78	0.96	0.72	0.99	0.91

[a] One can obtain $\hat{b}$ by dividing the coefficient of I^2 by the coefficient of I in the estimated function.

function—equation (1)—and three selected utility levels—$U(I)$—equations (2) and (3) were used to plot for each farmer three (E,F)-indifference schedules. To allow for comparisons with the (E,F)-indifference schedules, derived earlier, $U(I)$ values were those given by the transformed utility functions for the $E = F$, the certainty equivalence points on the (E,F)-schedules. The results are shown in figure 2. The correspondence in schedules is fairly close for farmers F4 and F2, and practically nil in the case of farmer F3. Again, we experienced more difficulty in obtaining points for utility function estimation from farmer F3 than from the other farmers.

The schedules derived indirectly were calculated assuming that the farmers' subjective income distributions were normal. If no particular distribution had been assumed and equation (4) instead of equation (2) had been used, the rational arc of the schedules would have had a more restricted range of F.[3]

AN APPRAISAL OF THE RESULTS FROM THE TWO INTERVIEW METHODS

Even if the farmers had assumed normal income distributions in answering the questions for deriving the (E,F)-schedules, exact correspondence between the two sets of (E,F)-schedules could hardly have been expected. Allowance has to be made for a range of interview errors that must inevitably creep into the procedures. These are often psychological problems such as interviewer-farmer rapport, the motivation of the farmer, and/or the farmer's possible feeling that the various questions asked of him are irrelevant. Most of the interview questions were hypothetical. No direct knowledge of whether the farmer would actually behave the way he said he would in a practical situation was obtained. Then again, the questions we were asking were not all directly related to the farmer's experience. His choices might have changed if he were to have become more familiar with the implications of his choice.

Our experience suggested that farmers had fewer problems in answering the (E,F)-questions than the gambling questions for the derivation of the utility function. The (E,F)-procedure enables the implications of a distribution of income to be readily summarized in terms of expected income and possible high and low incomes. The farmer can visually comprehend the implications of two income distributions and can himself move the smaller income strip to a point of indifference relative to the larger income strip. On the other hand, the gambling questions for the derivation of the utility functions were more abstract than the (E,F)-questions. The farmers were not used to thinking in terms of 50% probabilities of a high income and a low income as opposed to a certain income.

THE APPLICATION OF (E,F)-SCHEDULES

The (E,F)-schedules were derived for use in linear programming (LP) models for predicting farmer decision making, assuming that the farmer was concerned about the range of possible incomes as well as the expected income of a farm plan. Specifically, they were to be used in an aggregative programming model of Australian agriculture underway at the University of New England known as APMAA. As described in Kennedy and Francisco, focus-loss constraints suggested by Boussard and Petit have been incorporated in the representative farm LP models. However, as pointed out earlier, there are practical and theoretical difficulties in specifying F as some constant. (E,F)-indifference schedules provide the trade-off information for determining F.

One method for using the schedules to determine F would be to vary F parametrically in the focus-loss constrained programming (FLCP) model and to plot out on a graph the (E,F)-production boundary. By plotting on the same graph (E,F)-indifference schedules, the optimal

[3] This can be explained with reference to the equation for minimum F in terms of F and $U(I)$: $(bF^2 + F - a/4b)/(a + 1) = U(I)$. The use of Tchebycheff's inequality implies $a = 1/\alpha = 10$ which is greater than $\frac{t^2}{0.1}$. By considering the relevant root of the quadratic, it can be seen that if a is increased so is F for given $U(I)$. The rational arc will therefore have a more restricted range of F.

(E,F)-production point would be determined as the point of tangency to the feasible (E,F)-indifference schedule depicting highest utility.

However, this is not really an operational possibility for aggregative programming studies consisting of a large number of representative farm models. More attractive is the idea of modifying the objective function in the LP models from max E to max $[E - cF]$, where c is the trade-off coefficient between E and F determined from the (E,F)-indifference schedules. The problem with this is that c is itself a function of E and F and therefore cannot be definitively prespecified. It may therefore be necessary to follow an iterative procedure whereby c is varied until an (E,F)-LP solution is obtained in which the trade-off coefficient from the (E,F)-indifference schedules equals c. Another possibility would be to take account of declining (absolute) c with increasing F which is shown in some of the farmers' schedules. This could be allowed for in the LP model by specifying alternative values for F, with lower values of c corresponding to higher values of F. However, experimentation with the sensitivity of some LP solutions to date indicates that the value of c may not be critical.[4]

The (E,F)-analysis discussed so far has all been in terms of some specified probability level α, taken to be 0.1 in the case study interviews. In order to take account fully of Borch's point mentioned earlier, the possibility of trade-off between α, E and F should be considered. This of course adds a further dimension to the decision problem and implies that (E,F)-indifference schedules would logically have to be obtained for a range of α. However, if both the planned income distribution specified by the LP solutions and the subjective possible income distributions of the farmer are normal, then the optimal plan is independent of α. This is because under assumptions of normality (E,F)-analysis is equivalent to (E,S)-analysis.

The use of the modified objective function max $[E - cF]$ compared with max E and prespecifying F has the practical advantage of eliminating the problem of specifying infeasible LP problems by unwittingly fixing F at too high a value.

CONCLUSIONS

A simple method has been described for obtaining indifference schedules for expected income and focus-loss income. The method was devised bearing in mind the behavioral hypotheses of decision making of Shackle, and Boussard and Petit. The aim was to use the information from the indifference schedules for predictive rather than normative purposes.

While it is possible, given certain assumptions, to derive (E,F)-schedules indirectly by deducing them from utility functions derived by one of the conventional methods, the experience obtained in these case studies underlines the difficulties involved. It may be possible to raise theoretical objections against the type of utility function fitted, and the relationship between S and F may not be known with certainty. We found the direct method of obtaining (E,F)-schedules was relatively easy to apply and provided a flexible means for the farmer to express his preferences in terms of expected income and the variability of income.

It is undoubtedly more elegant mathematically to maximize utility defined by a quadratic function for income in a quadratic programming model than to use approximate and iterative LP methods. Our main concern is which approach leads to a better guide to farmer decision making for a given computing expenditure. Although we need more than case studies of five farmers to answer this question, this study suggests that the (E,F)-approach is a viable alternative to the (E,S)-approach.

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[4] For three APMAA representative farms, LP solutions were unchanged for a range of c from 0.4 to 0.9.

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Notes

THE SUBSTITUTION OF TECHNOLOGY FOR NATURE: THE CASE OF RECREATION

C. DIRCK DITWILER

The notion that technology can be used to alleviate or solve our environmental problems is heresy to many in view of today's new environmental ethic. An increasing number of people argue that we should rely less on technology to solve our environmental problems. Man should adjust to nature rather than degrade it with intensive applications of technology. He should preserve the natural environment rather than using (or abusing) it.

This notion, i.e., that we should preserve our environment, is often used as a basis for prescribing solutions to problems created in situations of excess demand for many natural resources. Excess demand often results in a degradation of the physical resource base as well as a degradation in the quality of the product or service produced from the base.

Many physical scientists, for example, have approached the degradation problem in terms of the physical constraints. This approach has led to their application of a "carrying capacity" concept. The general application of this concept appears to be gaining acceptance in many professions (Urban and Rural Related Lands Committee) and has already achieved legitimacy in specific application (Stankey and Lime). Carrying capacities are usually derived from physical dimensions of the natural environment and are often defined in terms of physical absolutes—e.g., unspoiled wilderness, pure water, and clean air. Thus, goals with respect to the physical environment can be explicit. It is relatively easy to discern the divergence between actual conditions and the ideal defined in terms of absolutes. The carrying capacity concept focuses on man's need to adapt to and function within the constraints imposed by the natural environment.

Many governmental natural resource programs reflect the notion that environmental concerns should dominate decisions regarding natural resource use. The federal and state agencies charged with producing natural resource oriented services have been given much of the responsibility for managing the natural resource base traditionally used in the production of the services. This responsibility tends to legitimize the traditional "nature-dominant" input/output relationships; this perspective has inadvertently focused attention away from the potential benefits to be derived from changing the input base for the production of goods and services which have traditionally been derived directly from elements in the natural environment. We have not given adequate attention to the possibility of orienting our production functions around an artificial environment rather than the natural environment. Contrary to a basic theme in the new environmental ethic, technology can be used directly to alleviate problems associated with man's use of the natural environment.

THE CASE OF RECREATION

The demand for outdoor recreation which has increased significantly during the past decade can be linked to many factors, including an increase in population, a change in the composition of the population, an increase both in the general level of affluence and in the amount of leisure time, as well as an increase in peoples' access to political processes by which they can register and defend their claims for recreational services. The increased demand for recreation has intensified the pressure on the natural resource base that supports recreation. This pressure in turn has often resulted in an adverse impact on the physical characteristics of the base, an increase in conflicts over the use of the base, and a decrease in the quality of peoples' recreational experiences.

The notion of physical carrying capacity of the resource base dominates the approach to a solution to these conflicts. Economic studies also reflect this focus. Studies on the demand side often prescribe user fees to restrict use in general, to divert users from high to low use areas within a given season, or to divert users to off-season use. On the supply side, studies typically focus on the adjustments in the input-output relationships of a given production function which increase output relative to input or on basic changes designed to shift the production function upward.

These economic studies have contributed to the solution of the perceived problem. However, their major limitation is the narrow perspective of the input base. For the most part, they emphasize traditional natural resource inputs.

A Bias to Nature

In his quest for leisure, man is often more interested in diversion than nature per se. However, he is often forced to find diversion in nature because he is not offered an alternative. And when man's recreational activities deteriorate a given natural resource base, the usual solution to the problem is

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to impose use restraints. Rarely is a more fundamental question asked: is the specific natural resource base (perhaps unique or relatively scarce) a necessary component of the recreational experience being provided? For example, do many or most trail bike and snowmobile enthusiasts need or prefer to carry out their sport on delicately balanced natural ecosystems? It may well be that the real experience which many people seek depends only indirectly on a natural environment. The same experience, or perhaps even an improved one, might be obtained from an artificial environment which could be tailor-made to include the desirable characteristics of the natural environment and eliminate the undesirable ones.

Krutilla acknowledges that we know little about the demand for outdoor recreation experiences that depend on unique phenomena. He concludes that "increasing congestion at parks . . . suggests there are no adequate substitutes for these rare natural environments" (p. 779). But we tend to lump outdoor recreation experiences together and assume they all require rare natural environments. Do we really know that recreation depends upon unique natural phenomena or upon natural phenomena at all?[1]

Krutilla also concludes that "unlike resource allocation questions dealt with in conventional economic problems, there is a family of problems associated with the natural environment which involves the irreproducibility of unique phenomena of nature . . ." (p. 784). The distinction made in appraisal theory between reproduction and replacement (cost approaches to value) appears relevant. Reproduction refers to reproducing a replica structure, whereas replacement refers to replacing the utility of the structure. The former focuses on physical existence while the latter focuses on utility. An analogy may be drawn with the human system. It is apparent that technology cannot reproduce a human organ as the body does, but it can replace the utility of some organs with artificial ones that serve the purpose of the natural organs. Similarly, for certain recreational experiences, artificial environments may replace the utility of specific natural environments.[2]

This is not to deny that there are certain experiences that depend upon natural environments or even unique natural environments. But if we identify all or even some of those experiences, it should be possible to reduce present conflicts over the use of the resources as well as maintain the quality of the natural environment. Krutilla readily assumes that substitutes for conventional natural raw materials will be found for the industrial and agricultural sectors. Why not assume that we can find a similar substitute for recreation?

Conceptually, a person's perspective dictates his response to an artificial environment. The existence of a wide range of perspectives has been discussed elsewhere (Ditwiler). Casual observation suggests that recreationists in the aggregate have a broad range of acceptance of artificial environments. Some people cannot achieve a desired recreational experience without experiencing nature in a state unaltered by man. Others are tolerant of a moderate substitution of artificial elements for natural elements. Still others do not even have to come into direct contact with a pristine or man-altered natural environment in order to secure benefits; many benefit from an environment simply by being aware of its existence. Moreover, peoples' vicarious experiences of natural environments probably greatly outnumber direct experiences, and there are many tangible means for such experiences: the spoken and written word, paintings, still and motion pictures, and the recent development of the experience booth or theater (discussed below).

Many other people do not even desire vicarious experiences of a natural environment. Their objectives for the use of and values with respect to the natural environment lead to their tolerating or even desiring a rather complete substitution of it by artificial elements. Examples are numerous and range from artificial turf for golf to man-made waterfalls to the artificial worlds of Disneyland.

Artificial Environments: Definition and Evolution

The definition of an artificial element or an artificial environment depends upon assumptions about man's relationship to nature. If man is viewed as one of many animals in the natural environment, his activities and artifacts are a natural part of that environment. Thus, a house built by man is "natural" just like a house built by beavers. In contrast, a more anthropocentric view implies that only non-man-made elements are part of the natural environment, that products produced by man are unnatural or artificial.

The validity of these divergent views will not be discussed here. It is sufficient to observe that man has generally acted as if he were not a part of the natural environment. Thus, artifactual features appear as artificial. In order to develop a framework for discussion, an artificial environment is defined as a natural environment which has been altered by man and an artificial element as a man-made element used as a substitute for a natural element.[3]

1 I'm not convinced that the kind of talent and imagination that went into developing the several Disneylands could not develop, for example, a "Yellowstone East" which could meet the demands of a large segment of the population in the highly populated East.

2 This argument seems to run counter to a fundamental conclusion reached by Barry Commoner, who concludes that we need to move from the use of artificial technology to natural technology in order to reduce environmental degradation. However, the argument here refers to the use of intermediate products and suggests the need to move in the other direction.

3 It is apparent that the definition of alteration is critical to this definition. The question is one of degree. For example, if the definition were couched in terms

Man's use of and ability to create artificial environments has grown over time. Early man viewed the natural environment as an enemy to be conquered. Man did not conquer, of course, but he did learn to reduce some of the harshness of nature by rearranging or modifying elements. A facet of this modification—to make resources available at times when and places where they do not occur naturally—was and still is one of man's prime activities.

The next stage in the evolutionary process of man's creation and use of artificial environments is his copying of natural elements. Man reproduces elements which he substitutes for natural elements. Examples of the reproduction or exact imitation of natural elements includes man-made snow and ice. Man-made elements, similar in function to natural elements but different in origin and structure, can be called artificial analogues. Analogues often overcome or reduce the limitations imposed on man by the natural elements they replace. Form utility is increased when man circumvents limitations imposed by nature. Examples include plastic snow mats for skiing and a thermal plastic material that substitutes for ice (discussed below). Man's control of these artificial elements is absolute or nearly so, thus greatly increasing their flexibility.

THE USE OF ARTIFICIAL ENVIRONMENTS IN RECREATION

The introduction of artificial environments may lead to more homogeneous user groups. An artificial environment designed to meet the needs of a homogeneous group could contain only those characteristics valued by the users and may result in an experience of increased quality. In addition, artificial environments may increase the productivity of a given resource base. Increased productivity may stem from the interplay of a resource input and time in the production of a given service. For example, the use of plastic snow for skiing, a man-made analogue to natural snow, is not limited by natural climatic conditions. Man-made plastic snow can be used to extend the skiing season into the summer months or even to provide skiing in areas that receive little or no natural snow (Christie). Increased output may also result from the multiple use of artificial environments. A man-made analogue for ice has been developed that has a plastic rather than a water base (Christie). The material, which can be applied directly over an existing hardwood gym floor, releases a lubricant under the pressure of a gliding skate edge. After ice-skating is completed, the "ice" can be removed and the area can be used for more conventional activities, e.g., basketball.

The natural environment may ultimately serve as a limiting capacity to artificial environments because of the need for physical space to carry out any activity. The need for such space cannot be eliminated even if the artificial environment is increased by infinite amounts. However, strategies can be adopted to minimize the impact of the space limitation. For example, there are some artificial camping areas which are stacked in layers or tiers. A "natural" setting is created by the use of artificial trees, shrubs, grass, waterfalls, etc. The campers and their camper pickups or trailers are lifted up into these units and people presumably carry on as if they were in a natural environment (Shew). Man is also attempting to overcome the limitations of physical space by building parks over freeways or on the tops of high-rise buildings and by using sanitary landfills for recreation spots.

Man's early confrontation with nature involved a modification or rearrangement of elements in the natural environment to better suit his needs. A modern day example of a rearrangement is the strategic placement of cut or potted trees for carving or plants for feeling and smelling in park or campground areas (Shew). The idea is a simple one—it is controlled consumption of specific attributes of nature. Resource managers have found it is more efficient to create an artificial environment designed expressly for purposive destruction rather than to try to prohibit all destructive activity in order to protect natural vegetation. The elements used are natural; the location, configuration, and use of these elements are programmed by man to reduce or eliminate degradation of the natural setting.

Another one of man's early efforts in the battle with nature was to contrive shelters to secure protection from the harsh extremes of climate. Climate has remained a major constraint on man's activities largely because of the cost of building structures to keep natural elements out. A recent technological breakthrough, an artificial shelter costing approximately $2 per square foot to construct in one to three acre parcels, could help increase man's control over climatic factors (Christie). The shelter should greatly increase the flexibility of man's use of both artificial and natural environments by permitting him to control the environment of large areas.

The substitution of artificial environments for natural environments will permit greater flexibility with respect to the location of certain services. Services which have been inextricably linked to a natural resource base will no longer be constrained by nature's capriciousness. Location decisions for such services can be guided by the location of effective demand rather than dictated by the location of the resource base. The need for a demand location orientation is evident in the Legacy of Parks Program. The majority of park area in the U.S. is located in the relatively undeveloped areas of the West where the natural resource base is large and the population relatively small. The intent of the pro-

of absolutes, a natural environment could conceivably be only that area where the foot of man has never trod. This is not the intent here. For a discussion of these kinds of issues, see Nash.

gram is to put the parks where the people are—in the East and in the urban centers; the use of artificial environments could greatly facilitate the program. An associated benefit is the potential reduction in fuel consumption by those who utilize resource-based facilities. Presumably, it would be much more efficient in terms of energy use to move the artificial facility close to the demand center rather than to continually move individual consumers to the facility. Another example of locational flexibility afforded by artificial environments is a concrete mountain built in the populated west part of the state of Washington to permit mountain climbing enthusiasts to undertake climbs covering the wide range of difficulties found in nature. The man-made mountain concentrates these climbs in one location; a climber would have to confront several mountains, perhaps hundreds of miles apart, to obtain a similar mix of climbs. Certain areas of the Southwest have artificial surfs for surf boarding enthusiasts. Not only is surfing physically removed from the ocean, thus relieving pressure on that resource, but the quality of the experience is reportedly improved because of man's ability to control the time, frequency, and size of the waves.

These examples involve the use of a physical copy or an analogue to physical elements found in the natural environment. However, the use of artificial environments has developed beyond the use of physical elements per se. Experience booths or experience theaters are prime examples. These facilities appeal to the senses (e.g., sight, sound, smell) and give the participant a psychological experience. For example, in the visitors' center in Yellowstone National Park, the Park Service has a wilderness experience booth which provides a means of communicating the benefits of wilderness to park visitors, many of whom have neither the time nor the inclination to get out in a natural wilderness. Thus, the Park Service seeks to enable people to experience wilderness while eliminating their need for the actual experience. However, the means to the end becomes the end; many people return to the booth several times for the experience itself.

CONCLUSIONS

To some, the above discussion may imply that artificial environments are a panacea for our natural resource and environmental quality problems. Although there appears to be reason for optimism, the real potential of artificial environments is yet to be determined.

What are the incentives for substitution on the supply side? We have a built-in physical as well as an economic imperative to consider alternative means of production for those goods and services which consumptively use natural resources. As the resource is used up, the physical imperative eventually forces a move to an alternative resource base which may be less natural resource intensive or even artificial in nature. In contrast, for goods and services that use natural resources in a largely nonconsumptive manner, such as many forms of recreation, we have only a weak physical imperative to consider alternative inputs. This physical imperative exists in terms of overuse and congestion but the impact is moderated through the quality dimension. In the case of outdoor recreation, many factors, including nonmeasurable benefits, externalities, collective goods, and the use of social rather than economic values to guide production, reduce the economic imperative. Thus, the incentive to look for alternative means of production is often buried under ambiguity and the political process.

The absence of strong endogenous incentives to look for alternatives, especially artificial alternatives, creates a special need for objective protagonists. Economists have a comparative advantage in meeting this need for they already have the necessary tool kit.

Producers' willingness to adopt a new technology centers on the issue of costs and net benefits of use. The cost of developing and introducing a man-made environmental element is positive and direct. In contrast, the direct cost of using elements of a natural environment is often negligible. Research is needed to determine the extent to which the external costs associated with the use of natural environments must be internalized before artificial elements will be adopted. Or, viewed from the other side, one could ask whether the external costs associated with the use of the natural environment will be reduced or eliminated if artificial environments are used. What is the nature and magnitude of these external cost reductions? Do they justify public subsidy of the use of artificial environments?

What are the substitution possibilities on the consumption side? We need to move away from the notion of the average recreationist and identify characteristic product preference, peoples' willingness to pay for a wide range of experiences, and the class of users. We specifically need to determine the dimensions of existing consumer acceptance of artificial environments. An educational extension program could increase that level of acceptance. Researchers could also identify the potential for increasing the quality of recreational experiences by diverting demand from natural to artificial environments.

The indirect effects of the use of artificial environments such as the manufacture, use, and ultimate disposal of artificial elements also need to be researched. Care must be taken to assure that the substitution of artificial elements for natural elements will in fact result in a net social gain. A substitution assessment must insure, for example, that environmental degradation is not merely transferred from one resource base to another.

The use of artificial elements in the production of recreational services is not new but the real potential has just begun to be tapped. There is little

chance that artificial elements will completely replace natural elements in the provision of recreational experiences. However, a full understanding of the impact of the use of artificial elements will lead to a broader range of choice. Increasing pressure on the natural environment combined with continued adverse impacts on both the physical environment and the quality of the services produced suggests that the time to scrutinize artificial alternatives is not only ripe, but overdue.

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THE PRICE AND INCOME ELASTICITIES OF HOME CONSUMPTION AND MARKETED SURPLUS OF FOODGRAINS

WALTER HAESSEL

Recently there has been a good deal of empirical research on the price responsiveness of peasant farmers as producers. (See, for example, Krishna [1967], Behrman, Dean, and the literature cited there.) Due primarily to a lack of data, there has not been any comparable research on the price responsiveness of peasant farmers for consumption or marketings. Most of the estimates on marketing response have used an indirect estimation procedure following Krishna (1962). Perhaps the only direct estimate of the short run responsiveness of marketed surplus has been that by Bardhan based on a mixture of cross-section and time-series data on a number of villages in northern India. I am unaware of any attempts to estimate the price responsiveness of peasant farmers as consumers.

Bardhan regressed the percent of foodgrains marketed on the total supply of foodgrains, the price of foodgrains, and several other variables using ordinary least squares. This procedure is correct only if price is not affected by marketings or output (i.e., if price is exogenous). It is difficult to believe that both price and output can be exogenous. It is true, as Bardhan argues (p. 53), that contemporaneous price cannot affect production until the next harvest. However, the causation can run the other way with supply affecting price in the same period. If each village is reasonably self-sufficient in foodgrains, the price must be endogenous to the system and will be affected by the quantity produced and marketed. Hence, ordinary least squares will not yield consistent estimates.

In this paper a model is developed of demand for home consumption, supply of foodgrains marketed, and price determination in a closed village. Part of this model is estimated using Bardhan's data. Price and income elasticities of demand for home consumption and marketed surplus are calculated as well as an output elasticity for marketings and a price elasticity of demand for the entire village community. This method of analysis provides more information than Bardhan's method and some of the results differ substantially.

THE MODELS

In this section a model is developed for a closed village community.[1] The total production (supply) of foodgrains (S) is allocated among consumption by the cultivators (C), marketings (M), and other net disposals to noncultivators (T) which consist of payments in kind for rent, wages, etc. Thus we have the accounting identity

$$(1) \qquad S \equiv C + M + T.$$

In a cross section, S may be considered exogenous since it does not depend on current price, and to the extent that T consists of contractual payments it will be exogenous too. Hence the cultivators' short run decision is to allocate $S - T = Q$ between consumption and sales. Consumption is assumed to depend on the relative price of the commodity (P) and net income of the farmers (Y), where Y includes the income from foodgrains consumed and sold.[2] Hence

$$(2) \qquad C = C(P,Y).$$

Since the allocation of $S - T$ between C and M involves only one decision, M must be a residual, and from equation (1) we have

$$(3) \qquad M = Q - C(P,Y) = M(P,Y,Q).$$

The demand for foodgrains by noncultivators (N) depends on the price of foodgrains and the income of nonfarmers Y^n as

$$(4) \qquad N = N(P,Y^n).$$

The market clearing equation is

$$(5) \qquad N = M + T.$$

Gross farm income depends on the value of foodgrain production as well as other income (Y^o) which

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[1] A closed village is one for which the net inflow or outflow of foodgrains is negligible. Jones (chap. 6) found that in Nigeria prices of foodstuffs in adjacent villages often differed by more than the cost of transport even when the majority of villages were net exporters to larger urban areas. Thus, the closed village assumption is sufficient but not necessary to guarantee that prices are influenced at the local level, presumably by total production among other things.

[2] The price of other commodities is implicitly taken as the *numéraire*.

is assumed to be exogenous. Since no data are available on costs, the income variable used is Y^o plus income from foodgrains net of other disposals. Thus

$$Y = PQ + Y^o. \tag{6}$$

Finally, the income Y^n of the villagers who are not farmers (e.g., traders) depends on the level as well as the composition of farm income, since these will influence the expenditures of the cultivators in the local markets. Y^n might also be expected to depend on the size distribution of the farms for the different villages. Hence we can write

$$Y^n = f(Y, P, S, T, Y^o, LY, I), \tag{7}$$

where LY is the percent of Y^o derived from livestock, and I is an index of concentration of cultivated acreage. This index increases as more of the land is held in large farms.

Assume a linear functional form for estimating the consumption equation as

$$C = \alpha_o + \alpha_1 P + \alpha_2 Y + e, \tag{8}$$

where e is a statistical error term with zero mean. Substituting equation (8) into equation (3), we find the estimating equation for marketings is

$$M - Q = -C = -\alpha_o - \alpha_1 P - \alpha_2 Y - e,$$

which is simply the negative of the consumption equation. Thus, it is necessary to estimate either the consumption or the marketing equation but not both. We choose to estimate the consumption equation. It can be shown that the short run total price elasticity of marketed surplus is

$$\eta = \frac{dM}{dP}\frac{P}{M} = \epsilon_{mp} + r\epsilon_{my}, \tag{9}$$

where $\epsilon_{mp} = \frac{P}{M} M_p$ is the pure price elasticity of marketings (i.e., ignoring the income effect of a price change); $\epsilon_{my} = \frac{Y}{M} M_y$ is the pure income elasticity of marketings; M_p and M_y denote partial derivatives of marketings with respect to P and Y; and $r = PQ/Y$. It can be shown this is identical to

$$\eta_p = -b(\epsilon_{cp} + r\epsilon_{cy}), \tag{10}$$

where $\epsilon_{cp} = \frac{P}{C} C_p$ is the farmers' price elasticity of demand for foodgrains; $\epsilon_{cy} = \frac{Y}{C} C_y$ is the farmers' income elasticity of demand for foodgrains; $b = \frac{C}{M}$ is the ratio of consumption to marketings of foodgrains; and C_p and C_y are partial derivatives. Thus the gross short run elasticity of marketings of foodgrains with respect to price is a mixture of the pure price and induced income effects and may be computed using either consumption or marketing elasticities.[8] The consumption version of this equation (10) is identical to Bardhan's version of Krishna's indirect estimation procedure (Bardhan, p. 52).

The long run elasticity of marketed surplus with respect to price is more complicated, since it involves supply (production) response as well as marketing response. This long run marketing response is much more likely to be positive than the short run response. Krishna (1967; 1962) has suggested an indirect method of estimating such a long run supply response with respect to price as

$$\theta = \sigma \eta_s, \tag{11}$$

where $\sigma = \frac{P}{S} S_p$ is the long run supply response and $\eta_s = \frac{S}{M} M_s$ is the gross elasticity of marketings with respect to quantity produced. Differentiating equation (2) with respect to S, assuming $T_s = 0$ (i.e., other disposals of foodgrains do not depend on the amount produced) and converting to elasticities results in

$$\eta_s = S/M - b\gamma\epsilon_{cp} - b\epsilon_{cy}(d + r\gamma), \tag{12}$$

where $\gamma = \frac{\partial P}{\partial S}\frac{S}{P}$ is the inverse of the price elasticity of demand for the entire community, and $d = PQ/Y$. A similar expression involving marketing elasticities may be derived from equation (3).

Thus it is apparent that η_s involves both a price and income response on behalf of the farmer. If all the parameters in equation (12) are available, an indirect estimate of η_s can be obtained.

ESTIMATION

The objective is to obtain estimates of ϵ_{cp}, ϵ_{cy}, ϵ_{mp}, ϵ_{my}, η_p, η_s, and γ. With the exception of η_s and γ, estimates of these parameters can be obtained by estimating equation (8). By assumption, P is endogenous to the system and since Y and Y^n depend on P, they are also endogenous. Hence, estimating equation (8) using ordinary least squares will result in biased estimates. Two separate estimation procedures were used. The first simply treated P and Y as endogenous and equations (8) and (12) were estimated by the method of two-stage least squares (TSLS) with S, Q, Y^o, LY, and I as instruments. However, since $Y = PQ + Y^o$ and Q and Y^o are exogenous, this seems to be relatively inefficient and a second estimation method was used which makes explicit the relation between the endogenous variables P and Y. A new variable was constructed as $\hat{Y} = Q\hat{P} + Y^o$, where $\hat{P}$ is a series of prices predicted from the reduced form. This new variable $\hat{Y}$ was treated as an exogenous variable and equation (8) was estimated

[8] This is considered to be a short run elasticity because the effect of a price change on production is assumed to be zero (i.e., $\partial S/\partial P = 0$).

using TSLS with $\hat{Y}$, S, Q, Y^o, LY, and I as instruments.[4]

Unfortunately there are no data available on Y^n and equation (4) cannot be estimated. This precludes a direct estimate of γ since γ depends on estimates of equations (2) and (4). Consequently, an indirect estimate of η_s from equation (12) is not possible. However, it is possible to go the other way around and obtain a direct estimate of η_s by estimating an equation of the form

$$(13)\quad M = \delta_o + \delta_1 S + \delta_2 T + \delta_3 Y^o + \delta_4 LY + \delta_5 I + e.$$

Computing η_s from an estimate of equation (13) would capture the total output effect on marketings which would include both the income and price effects resulting from variations in output.[5] This estimate of η_s can be used along with the estimates of the other parameters to solve for γ in equation (12).

Two sets of data are reported by Bardhan (pp. 59–60) for twenty-seven villages in Punjab and Uttar Pradesh in northern India. The data reported are on a per capita basis for the cultivating population for the entire village. In an effort to determine whether farmers above the subsistence level behave differently, the data are also reported for a subsample of farmers farming ten acres or more. These two data sets were used to estimate equations (8) and (13).[6]

[4] The $\hat{P}$ used in the construction of $\hat{Y}$ is the same $\hat{P}$ that is implicit in the second stage of the TSLS in the first procedure. The second stage predicted P for the second method will be different, since $\hat{Y}$ is considered exogenous and used as an instrument.

[5] Bardhan's inclusion of P as an independent regressor will result in a biased estimate of the coefficient on S (and hence η_s) if the expected covariance between S and P is not zero. In other words, Bardhan's estimate of η_s is net of, rather than inclusive of, the price effect.

[6] The variables in the present model were derived from Bardhan's data as follows: $S = X_1$, $P = X_2$, $Y = X_1\ (X_2 - X_6/100) + 100(X_3 + X_4)$, $T = X_1 X_0/100$, $Y^o = 100(X_3 + X_4)$, $M = X_1 Y/100$, $LY = X_4/(X_3 + X_4)$, and $C = X_1 - X_1(X_6 + Y)/100$. The X-variables on the right sides of the equations refer to Bardhan's data.

FARMERS' PRICE AND INCOME ELASTICITIES

Using the procedures discussed above, estimates for equation (8) for the two sets of data are presented in table 1. The two estimation procedures resulted in virtually identical estimates in all cases. The signs in all cases conform with a priori expectations.

Elasticities computed at the mean are presented in table 2. The elasticities are slightly higher (in absolute value) for the large farmer subgroup than for the entire sample. This suggests the larger farmers are relatively more price and income responsive than smaller farmers. However, the results do not vary substantially among data sets and estimation procedures.

Estimates of η_p are more interesting for purposes of pricing policy than the pure price response, since this is offset in part by the farmers' response to real income changes induced by price changes. Estimates of η_p in table 2 indicate that as the price increases the farmers will market more, contrary to the results of Bardhan who found the price elasticity of marketings to be negative for both data sets (p. 57).

Estimates of the total price elasticities (η_p) are calculated as linear combinations of the regression coefficients. These elasticities may not be significantly different from zero even if each of the individual coefficients was significant. To test whether the direct price effect and indirect income effects resulting from price changes offset each other requires a test of the hypothesis that $dM/dP = 0$. From equations (3) and (6), it is apparent that this is equivalent to a test of the hypothesis

$$(14)\quad \frac{dM}{dP} = M_p + QM_y = 0.$$

Assuming the estimate of the asymptotic variance-covariance matrix of two-stage least squares can be used as in ordinary least squares, a t-ratio was calculated on the estimates of equation (3) as

$$(15)\quad t = D\beta/(D\,\Sigma\,D')^{\frac{1}{2}},$$

where $D = (0, 1, \bar{Q})$ is a row vector, $\bar{Q}$ is the average production of foodgrains computed from the sample,

Table 1. TSLS Estimates of Equation (8)

Estimation Method	Entire Sample[a]			Large Farmer Subgroup[b]		
	Intercept	P	Y	Intercept	P	Y
1	20.8	−1.45	0.0105	30.1	−2.45	0.0142
	(7.80)	(0.68)	(0.0023)	(14.1)	(1.34)	(0.0041)
2	21.0	−1.46	0.0103	32.1	−2.63	0.0144
	(8.56)	(0.75)	(0.0025)	(17.2)	(1.64)	(0.0050)

Note: Numbers in parentheses are estimates of the asymptotic standard errors.
[a] Thirty-one observations.
[b] Twenty-seven observations.

Table 2. Estimates of Price and Income Elasticities of Consumption and Marketings

Data Set	Estimation Method	ϵ_{op}	ϵ_{oy}	ϵ_{mp}	ϵ_{my}	η_p	$\frac{1}{\gamma}$	t-ratio[a]
Entire sample	1	−1.99	0.60	3.05	−0.91	2.74	−4.29	1.94
	2	−2.00	0.59	3.07	−0.90	2.76	−4.28	1.79
Large farmer subgroup	1	−2.49	0.87	3.21	−1.13	3.08	−5.98	1.68
	2	−2.67	0.88	3.45	−1.14	3.32	−6.51	1.48

[a] The t-ratio is for the hypothesis $\eta_p = 0$.

β is a column vector of the estimated regression coefficients, Σ is the estimate of the variance-covariance matrix, and D' is D transposed. The results of these calculations are given in the last column of table 2.

ESTIMATES OF η_s AND $1/\gamma$

Turning now to estimates of the elasticity of marketings with respect to quantity produced, the following ordinary least squares estimates were obtained for equation (13).

For the entire sample,

$$M = -\underset{(1.26)}{2.98} + \underset{(0.0669)}{0.661}\, S - \underset{(0.00251)}{0.00165}\, Y^o - \underset{(0.202)}{0.595}\, T - \underset{(0.0252)}{0.0316}\, LY + \underset{(0.0218)}{0.0196}\, I.$$

$R^2 = 0.93.$

For the large farmer subgroup,

$$M = -\underset{(1.85)}{1.83} + \underset{(0.0688)}{0.643}\, S - \underset{(0.00269)}{0.00292}\, Y^o - \underset{(0.290)}{0.594}\, T - \underset{(0.0403)}{0.0371}\, LY.$$

$R^2 = 0.89.$

Calculating elasticities at the mean, η_s was found to be 1.97 and 1.75 for the two data sets. These estimates are slightly higher than Bardhan's estimates of 1.78 and 1.60.

As noted above, these estimates of η_s can be used along with the elasticity estimates in table 2 to compute estimates of the price elasticity of demand for the entire community ($1/\gamma$) by using equation (12). Estimates of $1/\gamma$ are presented in table 2. Comparing the estimates of $1/\gamma$ to the estimates of ϵ_{op}, the price elasticity of demand for the entire community is larger in absolute value than for the farmers. This suggests the nonfarmers' demands for foodgrains are relatively more price elastic than that of the farmers.

SUMMARY AND CONCLUSIONS

A model concerning the decision to allocate the net production of foodgrains between consumption and marketing was tested. The model specifies the consumption decision as a function of the price of foodgrains and the farmers' income, and marketings are treated as a residual. The model was estimated using two separate estimation procedures.

All of the elasticity estimates for the large farmer subgroup are somewhat greater in absolute value than for the entire sample. This suggests the larger farmers are relatively more price and income responsive than the smaller farmers. The estimated income elasticities of consumption are less than one in all cases, and the estimates of the price elasticity of consumption range from -2.0 to -2.7. The total short run price elasticity of marketings is positive in every case and ranges from 2.7 for the entire sample to over 3 for the larger farmers. This result is in direct contradiction of Bardhan who reported negative price elasticities for marketings using the same data but a different model.

Concerning the elasticity of marketings with respect to output, the evidence suggests this is substantially greater than unity. From the policy standpoint, this means that as output increases, the farmers will retain a smaller percentage for consumption purposes and make a larger percentage available for off-farm consumption. Finally, combining the elasticity of marketings with respect to output with the farmers' price and income elasticities of consumption (or marketings), it is possible to impute an estimate of the price elasticity of demand for the entire community. Using this procedure resulted in a price elasticity for the community of about -4.3 for the entire sample and a higher elasticity for the large farmer subgroup. This indirect estimate is somewhat tenuous but suggests the nonproducers are relatively more price responsive than the producers.

In conclusion, the evidence suggests that the farmers are price and income responsive as consumers, and higher prices will result in larger quantities marketed. Thus, a policy of attempting to stimulate output through higher prices will also be consistent with eliciting a larger proportion of the output produced for nonfarm consumers.

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THE PRICE RESPONSIVENESS OF PRIMARY PRODUCERS: A RELATIVE SUPPLY APPROACH

ANIMESH GHOSHAL

The controversy regarding the responsiveness of farmers to price in less developed countries (LDCs) is well documented. (For an excellent review of the literature, see Dean.) In this paper we examine and attempt to measure the price responsiveness of Liberian rubber farmers, using standard models as well as a "relative supply" model. The results should shed some light on the question of whether the behavior of farmers in LDCs conforms to what standard economic theory predicts, i.e., that a rise in price will lead producers to supply more of a commodity.

STANDARD MODELS

In supply response studies of the agricultural sector, production and acreage have both been used as the dependent variable. For a perennial crop like rubber, where a tree takes six to seven years to mature and is then productive for about twenty-five years, there are obvious problems with using acreage. Moreover, acreage figures which exist for Liberian farms are estimated by an extremely crude method. On the other hand, since all Liberian rubber is sold to three processors paying identical prices, data on production and prices are very good.

Several models have been used to deal with the difficulties mentioned above, since the problems are common to many tree crops. (Bateman [1969] discusses the standard models.) In a simple model developed by Stern (1965a), output depends on current price, mature acreage, and a trend variable for unspecified factors like changes in productivity. While mature acreage is unknown, planting is postulated to be a function of the current price. Thus, taking first differences, the change in output depends on the change in current price and the change in mature acreage, which is a function of the price lagged by the gestation period.[1] It may be more realistic to assume that planting decisions depend on expected future price than current price; this is done in Bateman (1965). An alternative approach, suggested by Ady, introduces the size of the current stand as a determinant of planting, and thus leads to an explicit capital stock model.

A Nerlove-type model may also be used. As Nerlove has shown, if full adjustment to changed conditions does not occur within the observation period, it still may be possible to derive long run estimates, assuming the long run equilibrium quantity to be a function of current price. Finally, a "naive" model may be used, with output being explained only by current price and a time trend.

The five models discussed above were tested using annual data for the period 1950–72. Only two equations turned out to be statistically significant at the 10% level using the F-test. Examining the price parameters of the significant ones, the "naive" model gave a price elasticity of supply of 0.12, but the t-test indicated this to be not significantly different from zero. Only the Nerlove model had a significant price parameter, with an elasticity of 0.22 (details available on request).

A RELATIVE SUPPLY APPROACH

All the tests in the previous section indicate a low price elasticity of supply. These results are consistent with those of earlier studies of rubber supply (Chan; Stern [1965b]; Wharton). The measured elasticity may be very low due to two different causes: (*a*) technical conditions are such that producers cannot vary aggregate production much in the short run, even if they want to; or (*b*) producers in LDCs are not maximizers in the sense postulated by economic theory. A good way of testing the latter explanation is to examine whether Liberian rubber farmers react to economic forces when they have the opportunity, i.e., by switching between different kinds of rubber (which is technically much easier than switching from rubber to another crop).

The rubber output of Liberian farms is not of homogeneous quality, but sold in several grades—latex, two grades of coagulum, and several varieties

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[1] Most of the supply response studies of tropical tree crops face the problem of inadequate data regarding planting, whereas production and price figures are generally much better. In all such cases, planting is postulated to depend in some way on current prices or current price expectations, i.e., price lagged by the gestation period is used as a proxy for the change in the (unknown) stock of trees. This is then used, together with current price, to estimate the supply response. The legitimacy of this procedure is somewhat questionable. If planting is in fact determined by price, then we can obtain a suitable measure of harvesting response to current price. However, if planting is independent of price, the proxy used for the stock of trees is inappropriate, and measures of the harvesting response are not meaningful. I am grateful to Wolfgang F. Stolper for pointing this out.

of off-grade rubber. A rubber tree, on being tapped, produces "raw" rubber in the form of latex. It can then be coagulated by adding formic acid or maintained in latex form by adding ammonia. The latter "spoils" more easily and has to be processed within 72 hours, whereas coagulum can be stored for weeks. (It may absorb dirt during storage and drop in gradation from "specification" to "nonspecification," the grading being done by visual inspection.) Apart from this, there are no technical restraints regarding the relative proportions to be marketed as latex or coagulum.

Latex generally carries a premium over coagulum, but the extent of the premium varies quite substantially from month to month. Usually, but not always, the prices move in the same direction. We will try to see the extent to which farmers switch between coagulum and latex in response to changes in relative prices. Bauer and Yamey did a similar study for cocoa and palm oil in Nigeria but did not produce any measures of responsiveness.

We postulate a functional relationship of the form

$$(1) \qquad \frac{Q_1}{Q_r} = f\left(\frac{P_1}{P_r}\right),$$

where $Q_1 =$ the quantity of latex, $Q_r =$ the total quantity of rubber, $P_1 =$ the price of latex, and $P_r =$ the "total" price of rubber.[2] Using the relative rather than the absolute quantity of latex enables one to see the extent of substitution and has the added advantage of eliminating problems caused by trend, seasonal variation, and other factors which affect all grades of rubber. In addition to equation (1), the relationship between the relative prices and quantities of latex and specification coagulum, the next highest grade is also tested.

$$(2) \qquad \frac{Q_1}{Q_s} = f\left(\frac{P_1}{P_s}\right),$$

where Q_s and P_s are quantity and price of specification coagulum.

Estimates are based on quarterly data for the period January 1969–March 1972, using linear and logarithmic forms and immediate and one-period lagged responses. A time trend was introduced but, as expected, did nothing to improve results and was dropped. Both linear and logarithmic forms and immediate and lagged forms gave highly significant equations. The logarithmic forms which give estimates of "elasticity" directly are reported below:[3]

$$(3) \quad \log (Q_1/Q_s)_t = \underset{(-1.83)}{-2.25} + \underset{(5.24)}{1.33} \log (P_1/P_s)_t; \quad R^2 = 0.71, DW = 1.72;$$

$$(4) \quad \log (Q_1/Q_s)_t = \underset{(-3.06)}{-4.06} + \underset{(6.23)}{1.71} \log (P_1/P_s)_{t-1}; \quad R^2 = 0.80, DW = 1.71;$$

$$(5) \quad \log (Q_1/Q_r)_t = \underset{(-1.40)}{-1.35} + \underset{(4.66)}{0.91} \log (P_1/P_r)_t; \quad R^2 = 0.66, DW = 2.05;$$

$$(6) \quad \log (Q_1/Q_r)_t = \underset{(-2.58)}{-2.53} + \underset{(5.82)}{1.16} \log (P_1/P_r)_{t-1}; \quad R^2 = 0.77, DW = 1.91.$$

The "elasticities" or measures of responsiveness are quite high, ranging from 0.91 to 1.71, indicating that Liberian producers do respond significantly to changes in relative prices. The one-quarter lagged equations (4) and (6), apart from somewhat better statistical fits, probably express economic behavior better than the unlagged ones, since it takes producers a while to adjust to changed conditions.

CONCLUSIONS

The standard supply elasticity tests indicate a very low degree of responsiveness to price. This may be due to a variety of reasons. As Saylor has pointed out in the case of coffee, tree crops are subject to what may be called "irreversible supply"—resources committed during a period of high prices remain locked into the product even when prices decline. Moreover, the technical conditions of rubber production are such that using annual price and quantity data may give misleading results in standard models, because of the overlapping of short and long run forces. A Nerlovian approach indicates some degree of long run price responsiveness, but, as Wickens and Greenfield have noted, Nerlove's model was originally applied to field crops in which long lags are absent and need not be successful for tree crops with a long gestation gap between planting and production. Finally, a relative supply test shows a very significant responsiveness of Liberian farmers to different relative prices, and it appears that their behavior can be explained by simple econometrics and economic theory, provided that technical constraints are taken into account.

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[3] The figures in parentheses show t-statistics.

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RESERVATION AND MARKET DEMANDS FOR SWEET POTATOES AT THE FARM LEVEL

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The quantity of sweet potatoes sold through commercial channels has remained rather stable over the last twenty years while the quantity of sweet potatoes used on the farms where they were grown has declined sharply. During this period, the real farm price of sweet potatoes has moved slightly downward as total acreage has declined from more than 400 thousand acres to a little over 100 thousand in recent years. Analysis of the trends suggests that total on-farm use of sweet potatoes is responsive to the price which producers receive for the quantities entering commercial channels. With on-farm use responding to price changes, determination of market price and the allocation of total production between farm uses and commercial sales must be analyzed simultaneously to identify and measure the impact of various determinants affecting the separate demand components. The results of a simultaneous estimation of the demand components for sweet potatoes and the use of these relationships to project prices and allocations of sweet potato crops in 1980 are presented below.

THE MODEL

The following simultaneous set of equations was specified for this analysis. The commercial demand for sweet potatoes is

$$(1)\qquad Q_s = f(P_s, N, Y, P_w, T);$$

the reservation demand for on-farm uses is

$$(2)\qquad Q_r = q(P_s, F, Z, P_w, T);$$

and the following identities are assumed:

$$(3)\qquad Q_t \equiv Q_s + Q_r,$$

$$(4)\qquad Q_t \equiv S,$$

where Q_r = total on-farm use of sweet potatoes in 1000 cwt.; Q_s = total sweet potato production sold off farms in 1000 cwt.; $Q_t \equiv S$ = total production in 1000 cwt.; P_s = real farm price (\$/cwt.) received for sweet potatoes; N = two-year moving average of total U.S. population in millions as of July 1; Y = real per capita personal disposable income in thousand dollars; P_w = real farm price (\$/cwt.) received for white potatoes; T = time trend (1949 = 1, 1950 = 2, etc.); F = total rural farm population in thirteen major sweet potato producing states in millions as of April 1; and Z = real per capita net farm income in thousand dollars (in thirteen major sweet potato producing states).

Price and quantity data for sweet potatoes are reported by crop year for thirteen major producing states. Two-year moving averages of all other economic variables reported by calendar years were used. All price and income data were deflated by a two-year moving average of the Consumer Price Index (1967 = 100).[1]

RESULTS

The estimated coefficients and associated asymptotic standard error estimates of the commercial and reservation demands for sweet potatoes obtained by three-stage least-squares procedures based on 1949–72 crop years are

$$(5)\qquad Q_s = \underset{(2{,}185)}{7{,}609} - \underset{(196)}{1{,}606\,P_s} + 59\,N + \underset{(1{,}326)}{947\,Y} + \underset{(234)}{479\,P_w} - \underset{(78)}{271\,T},$$

and

$$(6)\qquad Q_r = \underset{(4{,}083)}{10{,}180} - \underset{(205)}{1{,}371\,P_s} + \underset{(331)}{829\,F} + \underset{(1{,}023)}{1{,}076\,Z} - \underset{(254)}{375P_w} - \underset{(602)}{2{,}401\,\ln T}.$$

Correct signs of the coefficients were observed in all cases where prior expectations existed such as negative price-quantity relationships, a substitution effect of the price of white potatoes on sweet potato demands, and the decline in farm population shifting the reservation demand downward. The estimated price-quantity relationships for sweet potatoes imply that the responsiveness of nonfarm uses to price changes is slightly larger in absolute terms but considerably smaller in relative terms than the responsiveness of on-farm uses. The coefficients indicate that a 10¢ increase in the real price of sweet potatoes resulting from a reduced supply of around 298 thousand cwt. would involve a reduction of approxi-

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[1] Another paper presenting additional background information about the industry, detailed documentation of data sources, and further explanation of the economic model is available upon request from the authors. One aspect of the economic model is that a unitary population elasticity at mean values was assumed in the commercial demand equation. Therefore, the coefficient of N was fixed rather than statistically estimated.

mately 161 thousand cwt. for off-farm uses and around 137 thousand cwt. reduction in on-farm uses. These coefficients imply an inelastic (−0.65) commercial demand but an elastic (−1.25) reservation demand at mean values. Both of the above elasticity estimates are larger in absolute value than the price elasticity of −0.50 reported for sweet potatoes in George and King.

Decreases in the reservation demand were strongly associated with the declining rural farm population in the thirteen major sweet potato producing states. The elasticity of the effects of changes in farm population implies a change of 0.96% in on-farm demand for a 1% change in farm population. The coefficient of the total population variable in the commercial demand equation was restricted by assuming a unitary elasticity of demand with respect to population changes at mean values.

The income elasticities based on the estimated coefficients were around 0.21 for both equations. Given the magnitude of the standard errors, however, the results are generally consistent with the zero income elasticity for sweet potatoes reported in George and King and an estimate of −0.07 for consumers of sweet potatoes reported in Raunikar, Purcell, and Elrod. The latter estimate was not statistically significant from zero.

Substantial downward shifts in both demand functions related to time were observed. The estimates imply that the annual average shift to the left in the commercial demand function was around 270 thousand cwt. per year after accounting for the effects of other factors, whereas the reservation demand was shifting to the left around 100 thousand cwt. in 1972 and 1973.

The estimated coefficients for the price of white potatoes were positive in both demand functions. These relationships suggest a substitution effect between the two types of potatoes.

Equilibrium farm prices and market allocations were calculated from solved reduced-form equations for the sample period for purposes of comparison with observed values.[2] Observed and predicted values of the endogenous variables indicated that in more than half the cases, the predicted price differed by less than 5% in absolute value from the observed price. In only two years were deviations slightly above 10%. The predictions of commercial sales were substantially better. The error in predicting commercial sales was less than 1% for almost half of the observations.

Predictions for 1980 were calculated from the reduced-form equations for alternative quantities of total production, projected values of the income, population, and the real price of white potatoes.[3] These projections indicate that the same level of total production in 1980 as in 1972 would produce a slight decline in real farm price along with a small decrease in commercial sales. A total production of sweet potatoes in 1980, 20% above the 1972 quantity resulted in a predicted price lower than any real price observed between 1949 and 1972. On the other hand, a 20% reduction in production resulted in a farm price of 25¢ above the 1949–72 average real price with on-farm use reduced by more than 50% to 907 thousand cwt. and commercial sales reduced to 9,056 thousand cwt., a decline of slightly less than 15%. Projected on-farm use had a larger variation relative to commercial sales for alternative quantities of total production because of the larger price elasticity of demand for on-farm uses relative to commercial sales noted earlier.

SUMMARY AND CONCLUSIONS

Results of this analysis indicate that the two basic components of aggregate demand for sweet potato utilization have considerably different price elasticities. On-farm uses of sweet potatoes appear to be relatively more responsive to price changes than off-farm utilization. Most of the decline in total production during the last twenty-four years parallels the decline in on-farm use, which in turn is related to the decrease in farm population in the thirteen major producing states and to the associated disappearance of many small farms. The small positive income coefficient for commercial demand indicates that future increases in consumers' real disposable incomes are not likely to expand nonfarm households' demand per capita for sweet potatoes.

Projections for 1980 suggest that increases in population will not be sufficient to offset a continual downward shift in commercial demand with the same total production as 1972 resulting in a slight reduction in real farm price. Therefore, unless technological advances permit reductions in the real cost of producing sweet potatoes, there appears to be little chance that there will be any expansion in this in-

[2] The coefficients and estimated asymptotic standard errors of the solved reduced-form equations for P_s and Q_s are

$$\begin{aligned} P_s = \underset{(1.74)}{5.98} - \underset{(0.000035)}{0.000336\,Q_t} + \underset{(0.002)}{0.02\,N} + \underset{(0.44)}{0.32\,Y} + \underset{(0.11)}{0.29P_w} \\ + \underset{(0.11)}{0.28\,F} + \underset{(0.34)}{0.36\,Z} - \underset{(0.01)}{0.09\,T} - \underset{(0.23)}{0.81\ln T,} \end{aligned}$$

and

$$\begin{aligned} Q_s = -\underset{(2507.7)}{1987.6} + \underset{(0.040303)}{0.539469\,Q_t} + \underset{(2.4)}{27.2\,N} + \underset{(610.2)}{436.2\,Y} \\ + \underset{(127.6)}{18.4\,P_w} - \underset{(171.6)}{447.1\,F} - \underset{(544.1)}{580.5\,Z} \\ - \underset{(36.92)}{124.52\,T} + \underset{(358.3)}{1295\ln T.} \end{aligned}$$

[3] Real per capita disposable income was assumed to increase at an average annual rate of 3%. Real net farm income per farm resident was projected to increase by the same absolute amount as real disposable income per capita in the United States. Total U.S. population was assumed to increase at an average annual rate of 1%. Total farm population in the thirteen major producing states was projected to decline by a little over 200 thousand. The real price of white potatoes was assumed to be the average observed during 1949–72.

dustry in the near future. A slight contraction in total sweet potato production (perhaps a continuation of the trend of the late 1960s) appears more likely, with the rate of the decline in total acres greatly influenced by the rate of increase in yield per acre.

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A PRODUCTION FUNCTION MODEL FOR AGGREGATE TIME-SERIES DATA

C. ROBERT TAYLOR

A problem in using survey data on yield and input levels in estimating a production function for commercial farmers is that often only averages of individual farm or field input levels are available. Since the average data points should lie below the true production function (as long as it is strictly concave from below), traditional regression models applied directly to the average data will not yield an estimate of the true function unless it is linear (Taylor and Swanson). In this note, a model specification is presented which makes estimation of true production functions from aggregate farmer experiences more likely than under traditional specifications. To estimate this model, time-series data on the variation of input levels as well as the average input levels are needed. While the variation of input levels are often not available for past surveys, such data could be easily made available in future surveys. For the model specification presented in this note to provide meaningful estimates, the necessary conditions are: (*a*) that the area under study be homogeneous in that it can be represented by a single production function, (*b*) that there has been a significant change in the distribution of the input levels over the observation period, and (*c*) that all inputs not included in the analysis are kept constant.

The model specification is based on the following identity. The actual (observed) average yield is a summation over all input levels of the product of the unobserved yield at a specific input level and the fraction of farmers applying that level. This identity is substituted into an hypothesized production function which relates the unobserved yields to specific input levels in order to derive an equation which can be estimated using ordinary least squares. The parameters characterizing this regression equation are the parameters of the production function. For simplicity only one input is considered in the derivation.

The production function is assumed to be quadratic in the level of the input X.

$$(1) \qquad Y_t = a + bX_t + cX^2{}_t + e_t,$$

where Y_t = the predicted yield for a specific level of the input X, that is, a point on the production function, and e_t = the error term with a zero expected value.

Consider now the expected value of equation (1):

$$(2) \qquad E(Y_t) = a + bE(X_t) + cE(X_t{}^2).$$

Since

$$(3) \qquad V(X_t) = E(X_t{}^2) - [E(X_t)]^2,$$

equation (2) can be expressed as

$$(4) \qquad E(Y_t) = a + bE(X_t) + c[V(X_t) + [E(X_t)]^2].$$

Thus, the parameters can be estimated given information on the means of Y_t and X_t as well as the variance of X_t for each year t.

The power of this method in relation to the changes in the variation of the use rates of the inputs is unclear at the present time. However, the greater the change in the mean and variance of X over the observation period, the more confident we can be in our estimates of the parameters.

By the logic used above, it can be shown that a quadratic response function for multiple inputs can be estimated with knowledge of the means and variances of the inputs if there are no interactions between the inputs. In the case of interaction between the inputs, one must have knowledge of the covariances of the inputs in addition to the means and variances in order to estimate a quadratic response function.

The quadratic production function provides a simple illustration. Other popular types of functions such as the cubic, square root, transcendental, and Cobb-Douglas can also be estimated. However, these functions generally require for estimation complete knowledge of the distribution of input levels rather than just the mean and variance of input levels as required by the quadratic function. With some of these functions, such as the Cobb-Douglas and transcendental, iterative least squares must be used to estimate the parameters.

A desirable way to use the observations on commercial farmers in estimating a production function is to directly estimate a function from a time-series of individual cross-sectional observations on yield and input levels. From a conceptual standpoint, this method is preferred to the one presented in this note. However, the method presented here is a more practical alternative in terms of reporting and using survey results. Furthermore, only aggregate data may be available to the analyst. As indicated, a

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quadratic response function, which is widely used in analyzing experimental response data, can be estimated with information only on average yield, mean input levels, variances of the input levels, and, if more than one input varies, the covariances of the inputs. Since most surveys (such as the Economic Research Service's objective yield survey) already report yield and mean input levels, the additional data needed to estimate this model could be easily provided by computing and reporting the variance-covariance matrix for the data set. No changes in the survey itself would be required.

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SIGNIFICANCE TESTS OF REGRESSION COEFFICIENTS: AN ADDITIONAL REMINDER

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Authors in a number of recent *Journal* articles have referred to the "significance" of regression parameters based on two-stage least-squares (2SLS) or three-stage least-squares (3SLS) estimation procedures (Holland, p. 304; Radtke, pp. 590–91; Tryfos, p. 110). As is well known, 2SLS and 3SLS estimators are consistent and asymptotically normally distributed (Theil, pp. 497–98). However, 2SLS and 3SLS estimates are biased and for small samples, the ratio of the estimated coefficient to its estimated standard error does not follow the t distribution (Christ, pp. 515–16; Kmenta, p. 584). Thus, levels of significance based on a standard t distribution are not strictly applicable for 2SLS, 3SLS, or other simultaneous estimates.

Furthermore, even tests of significance for coefficients of models estimated with ordinary least-squares (OLS) procedures must be interpreted with extreme caution. There is a substantial amount of literature dealing with the bias implicit in the use of the t test as an initial step to select regressors (see, for example, Wallace and Ashar, pp. 172–78). Freund's recent comments dealing with the applicability of the t test to coefficients of "truncated" models estimated with the ubiquitous "stepwise" regression routines are often relevant (p. 192). It has been shown elsewhere (Debertin and Freund, p. 3) that when OLS regression equations are estimated with the "stepwise" routine, type I error probability is maintained on the basis of the initial rather than the final variable set. Theil argues that it is sensible to interpret confidence intervals and test statistics quite liberally when more variables are presented for possible inclusion in a regression model than are included in the final variable set. Under such conditions "a 95 percent confidence coefficient may actually be an 80 percent confidence coefficient and a 1 percent significance may actually be a 10 percent level" (pp. 605–06). In short, the usual reporting of levels of significance is often misleading. However, the ratio of the coefficient to the standard error remains a qualitative guide to the relative importance of individual regressors.

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REAL PROPERTY TAXES AND FARM REAL ESTATE VALUES: INCIDENCE AND IMPLICATIONS: COMMENT

BRADY J. DEATON and S. DARRELL MUNDY

Pasour demonstrated the capitalization of differential property tax burdens into farm values. These results were based on the coefficients of a multiple regression cross-sectional statistical model for 83 of 100 counties in North Carolina. Urban counties were omitted from the study. Pasour's analysis yielded a negative, statistically significant regression coefficient ($\alpha = 0.05$) for the effective tax rate variable in an equation with farmland values as the dependent variable, implying that the tax rate is capitalized to some extent into land values. This excellent report clarified conflicting but very important issues in the property tax literature.

The purpose of this comment is not to criticize the Pasour article but rather to discuss further implications for property values arising from capitalization of differential property tax rates. A case in point arises from a shift in the method of assessment from constant proportional to preferential assessment of farmland at a lower percentage of market value such as that recently enacted in Tennessee.[1] This system assesses farmland at 25% of its "fair market" value and does not base land values on "use-value" in farming. The shift to a system of preferential assessment influences the magnitude of capitalization of the effective tax rate from county to county. This differential effect occurs for two reasons: (*a*) each category of taxable property when assessed at a different ratio is associated with its own unique effective tax rate equal to the nominal rate times the assessment ratio for that category, and (*b*) differences exist among counties in the magnitudes and proportions of total market value of property categories. The effective tax rate for each property category in any tax period is a function of the revenue needs of the taxing unit, the nominal tax rate, the assessment ratio for that category, and the distribution and magnitudes of market values of all the various property categories.

For purposes of illustration, county revenue needs, total property values, and the mix of category market values can be held constant from one taxing period to the next for two counties (or other taxing unit), while assessment ratios (the main variable of interest here) and the nominal rate are allowed to vary. Then, tax burden changes within and shifts among property categories can be evaluated and compared both within and between counties.

Therefore, assuming equal nominal tax rates in two counties prior to initiating the system of preferential assessment, the same total revenue demands, and equal total taxable property values, the cost to farmers will vary by county according to the ratio of farmland property value to total real property in each county. Once preferential assessment is initiated, the nominal tax rates adjust in the two counties to yield a constant revenue stream. Where the ratio of farm to total property value is very high, there would be little shift in property tax burden from farmland to other categories, whereas in a county with a low ratio of farmland to total property value, there would be a significant tax burden shift away from farmland to property with higher assessment ratios such as commercial, industrial, or utility.

If decreases in the effective tax rate are capitalized into land values, the capitalization in the county with a high farm to total ratio would be very low, or even negligible, because the effective rates would decrease very little. (The nominal rate would increase proportionally to offset the lower assessment ratio on the farmland category—the predominant category.) Therefore, farmers would experience only slight, if any, shifts in actual farm value. However, in the county with a low ratio of farm to total property value, a significant relative increase in farmland values would occur because the nominal rate would change very little to offset the lower assessment ratio on the farmland category—the less significant category in this case.

If Pasour's results are representative of recent events in Tennessee, farmland values have increased as a result of preferential assessment especially in counties with low ratios of farmland to total property value. As in most states, these Tennessee counties are primarily around the major urban areas—

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[1] An amendment to the state constitution in 1972 provided preferential assessment at a ratio of 25% of market value for both farmland and residential units rather than the consistent 40% assessment ratio which prevailed for all property categories prior to that time. Commercial and industrial property remain at the 40% level and utility property was increased to 55%. Historically, a low assessment ratio for farm property was the norm. However, a 1967 law attempted to introduce some consistency into the assessment process by establishing a 25% assessment ratio for all property with annual 5% increments to follow until the 40% level was reached. Apparently, the public had been quite content with the informal "preferential" assessment that had been in practice. Witness, then, the reaction of the voters in reinstituting a "formal" system of preferential assessment for farmers and homeowners.

Chattanooga, Knoxville, Nashville, and Memphis. Pasour omitted seventeen urban counties from his study where the capitalization effect would likely be most significant. Nevertheless, the same implication follows from his results via the shift in the effective tax rate for each property category.

The above implication is given further credence by a similar study currently in progress at the University of Tennessee (Mundy, Gray, and Thomsen). The study is basically an extension of the Pasour model and yielded similar results with all Tennessee counties (rural and urban) included in a cross-sectional analysis. For the purpose of comparison, the coefficient of the natural logarithm of the effective tax rate was -47.2. The signs of the estimated coefficients of all independent variables agreed with theoretical expectations, and nine of the ten had t-ratios near two or larger. The coefficient of determination was 0.87 and the standard error of the estimate was $41.83 (mean value per acre for ninety-five counties was $260.44 in 1969).

Like Pasour's findings, the Tennessee results imply that farmers in urban/suburban counties obtain a windfall gain in property values as a result of preferential assessment. Of course, an interaction occurs over time between the increased value of farmland and the new tax rate to yield a new proportion of tax burden to the farmer, but the net effect would be a lessened tax burden on the farmer especially in those counties with a small proportion of farmland property. Hence, a lower tax burden is granted temporarily to farmers whose lands have greatly increased in value due to the pressures of suburbanization.

Of course, as farmland values increase via the capitalization process, the ultimate magnitude of the shift in tax burden cannot be determined until years after the inception of preferred assessment. The ultimate magnitude of the tax burden depends on the new tax rate and the resulting increase in farmland values from capitalization. So the extent of decline in the farmer's property tax burden is not at all clear from a cross-sectional analysis using only contemporaneous data. At this time, time-series data for a sample of farms by county is unavailable for the State of Tennessee to illustrate the long run effect on land values.

Recently, many Tennessee farmers, especially those in and around urban areas, have been upset because they perceive no tax break resulting from the constitutional amendment. They expected their property value to be based on its "use-value" in farming, thinking erroneously that this was an objective of the constitutional amendment. The capitalization effect may also help explain the unrest among farmers in the urbanizing areas. Moreover, a simultaneous reappraisal of land values resulted in higher values on some farmland due simply to more accurate appraisals.

For these reasons, farm values could rise considerably and offset most of the advantages gained by preferential assessment. Furthermore, capitalization of a lessened property tax burden works against the objectives of preferential treatment based on market value assessments and does not compensate for the lack of Green Belt laws and use-value assessment which would declare farmland in these areas as being relatively "permanent" farmland. Speculation, as well as the demand for nonagricultural uses of agricultural land in and around urban areas, has a significant impact on succession in land use. Under most contractual arrangements related to Green Belt laws and preferential assessment based on use-value, these diverse elements of demand are not allowed to drive up farmland valuation for tax purposes.

In conclusion, Pasour's results and further corroboration at Tennessee illustrate more thoroughly the ramifications of the property tax and may help explain farmers' continued concern about property tax issues in spite of relatively low tax burdens in most southern states. More than anyone, farmers may be aware of the capitalization process and its ultimate effect on land taxation. They may end up paying practically as much after preferential assessment as before, if sufficient time has passed to allow for reappraisal in response to the increase in market value. Preferential assessment based on use-value rather than market value is clearly the preferable policy for reducing the long-term property tax burden on farmland in urban-suburban counties. However, neither of the two policies holds much promise of tax burden reduction for the farm sector as a whole in predominantly rural farm counties, although distributional differences between the two policies would most likely result within the farm sector itself.

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EFFICIENCY AND EQUITY IN NATURAL RESOURCE AND ENVIRONMENTAL POLICY: COMMENT

CLIFFORD DICKASON

Professor Haveman appears to err in his statement (1973, pp. 872–73) that the traditional action-agency discount rate employed to establish present values of future impacts has been scarcely one-half of that necessary to keep highly valued private resources from being diverted to lower valued public uses. By that statement he means—as expounded in Baumol; Haveman 1972; and U.S. Congress—that the appropriate discounting rate for future project benefit streams should parallel the market interest rate at the time of project planning or approval. This brief comment challenges that conclusion.

The assumptions underlying the price valuation of the future benefit stream must be consistent with the assumptions governing the choice of the discounting rate used to discount future benefits. It would be inconsistent to evaluate future project benefit streams in current dollars (which is the practice), if the discounting rate was based upon the market interest rate, which is affected partly by inflation. To do so would unfairly handicap public project proposals, vis-à-vis business enterprises' investments.

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It would be appealing, in the "invisible hand" sense, for the public works discounting rate to rise and automatically discourage public project construction at times of great private investment demand (and resultant higher market interest rates). Still, in actual fact, the public project appraisal and approval process is such that if a project is approved at a time of low interest rates, the most intensive construction outlays may well occur at a time of high private investment demand. Therefore, the "automatic" principle might better be foregone in favor of conscious decisions on timing of construction.

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A PRACTICAL WAY TO SELECT AN OPTIMUM FARM PLAN UNDER RISK: COMMENT

PETER J. BARRY and LINDON J. ROBISON

Scott and Baker used Baumol's expected-gain confidence limit criterion to design a framework for the practical implementation of risk programming analysis. They argue, and we agree, that perceptive commercial farmers are capable of processing risky information in terms of their own risk-return preferences. However, we are concerned that the procedures Scott and Baker suggest for evaluating risk results are somewhat obscure and may not lead to the best choice. Accordingly, in this comment we use lexicographic utility analysis to extend their treatment of risky information. In addition we show how Baumol's criterion or stochastic dominance, together with a "safety-first" rule, lead to similar choices from the set of E-V efficient portfolios.

Baumol's criterion for reducing the set of efficient portfolios was based on deriving the lower confidence limits (L) for alternative portfolios and is expressed as

$$L = E - K\sigma, \tag{1}$$

where E = expected returns, σ = standard deviation of returns, and K = a constant determining the probability of E exceeding L.

For a normal distribution, the choice of K can be readily associated with known, tabulated probability levels. Similar implications can be drawn for nonnormal distributions although the calculations of confidence limits are more demanding.

Baumol suggested that portfolios from the E-V set are inefficient by his E-L criterion if there exists another portfolio with a greater expected value and a greater than or equal lower confidence value L. Hence, the efficient E-L set would include all portfolios to the right of the maximum point (M) on the L function in figure 1. The maximum of the L function is found by specifying the relationship among members of the E-V efficient set as

$$\sigma = f(E). \tag{2}$$

Substituting equation (2) into equation (1) and differentiating with respect to E, we obtain the solution $f'(E) = 1/K$, a portfolio in the E-V set which maximizes the L function.

Scott and Baker suggest that decision makers would express increasing risk aversion by choosing portfolios at the peak points of successively lower confidence limits. Lowering the confidence limit by designating higher values of K causes the peak to shift down and to the left. In their example, if K were set equal to zero, then X_9 is selected; if $K = 1$, X_7 is selected; if $K = 1.96$, X_6 is selected; etc. Hence the optimal choice according to Scott and Baker results in maximization of equation (1).

Since Baumol intended K only for identification of the E-L efficient set, to use it as the basis for maximizing utility is hard to rationalize. Furthermore, since any portfolio from the E-V efficient set could maximize equation (1) by appropriately specifying K, additional information is required for usefully applying the Baumol criterion.

Several authors have suggested the use of lexicographic utility analysis (Ferguson). Halter and Dean and others have applied it in a safety-first context (Roy). We suggest that it can be used in combination with the E-L efficient set. It seems reasonable to assume that managers have sequential objectives (Lin, Dean, and Moore), the first perhaps being the attainment of some threshold level of income (E-min.) with a high degree of certainty (e.g., 97.5%). This safety-first criterion assures the decision maker that future obligations for living expenses, debt repayment, resource replacement, holding liquid reserves, etc. can be met with a high degree of certainty from earned income without forcing liquidation of assets or unplanned, additional financing. Other utility objectives are considered only after meeting the threshold level of income.

In general, lexicographic utility can be formulated as

$$U = f(Z_1, Z_2, \ldots Z_N). \tag{3}$$

We consider a two-variable utility function where U = total utility, Z_1 = a risk averting goal stipulating that income must exceed threshold income E-min with probability P, and Z_2 = a profit goal (maximizing expected returns).

Thus, in sequential fashion, the decision maker first determines a threshold level of income and the probability with which incomes must exceed this level. The designated probability is used to derive the E-L efficient set. Next, the decision maker identifies portfolios in the E-L set that meet the threshold income, and finally chooses among the qualifying plans on the basis of the highest expected values (E).[1]

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[1] Assuming constant marginal utility of expected income after satisfying goal Z_1 provides a method of obtaining a unique solution among the E-V efficient portfolios. However, the second element (Z_2) of the two-variable utility function need not be profit maximization but could also include a measure of risk and returns.

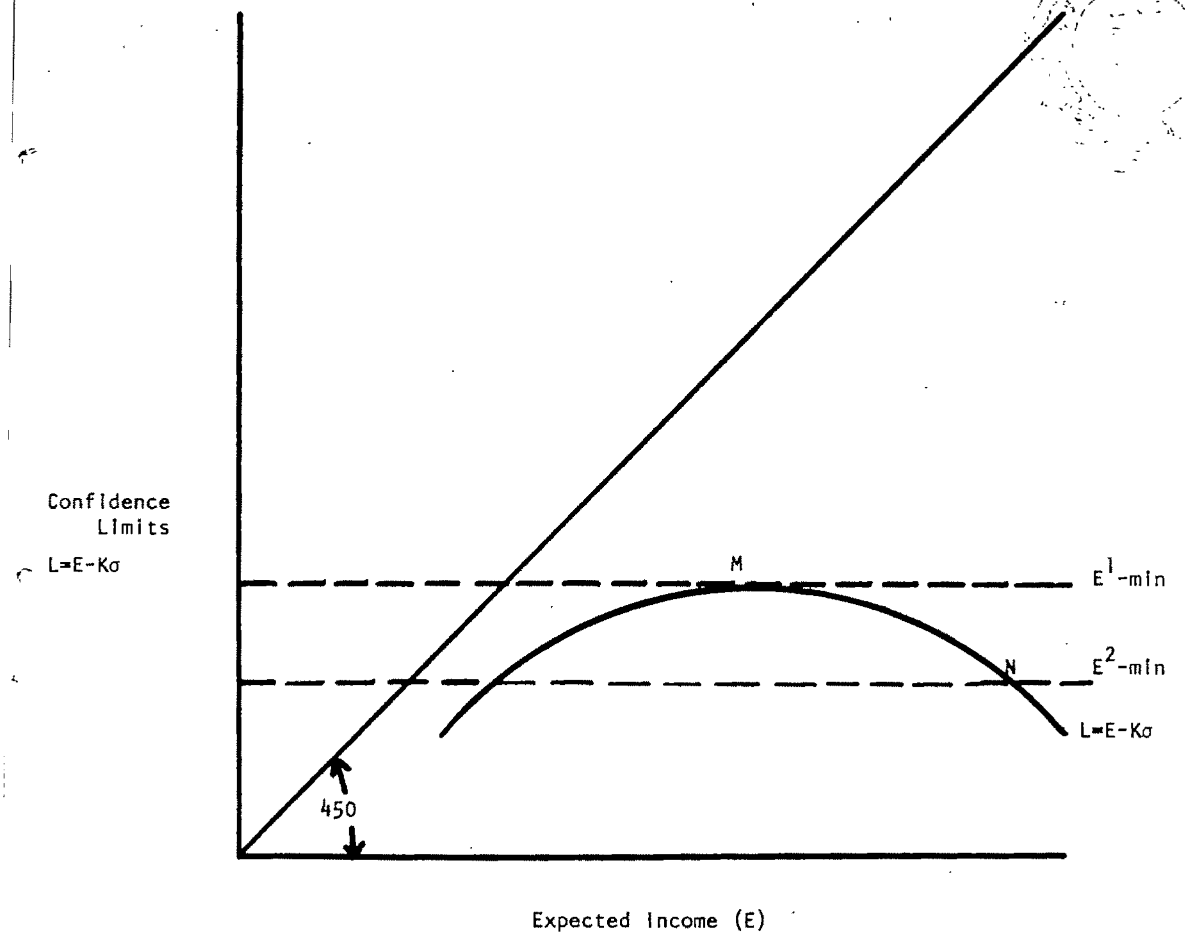

Figure 1. Derivation of Baumol's expected-gain confidence limit and selection of *E-L* efficient set.

If no portfolios meet the threshold income with the required probability, then presumably the portfolio coming closest to meeting goal Z_1 is chosen, i.e., the peak point of the L function. Alternatively, the decision maker could consider revising his requirements for threshold income and probability until one of the portfolios on the L function becomes satisfactory, i.e., the tangency point (M) between E^1-min and L in figure 1.

However, if threshold income E^2-min can be met by several portfolios, thereby implying attainment of goal Z_1, then the feasible set of E-L plans will lie on the interval MN of confidence curve L with the best choice being the portfolio lying farthest to the right on this interval. This portfolio satisfies the risk aversion goal (Z_1) and then maximizes the profit goal (Z_2).

Suppose, for example, that the decision maker considering the portfolios in table 1 stipulated that a threshold income of $22,000 was needed to cover consumption, debt, and other fixed obligations. Moreover, he preferred that income would exceed this level about 97.5% of the time. The L values for the respective portfolios are indicated in table 1, column 1. The efficient E-L set meeting E-min contains X_6, X_7, and X_8 with X_8 being the best choice. Its income will exceed $22,000 more than 97.5% of the time and it yields the maximum expected income of $28,678.

The stochastic dominance criterion (Hadar and Russell; Hanoch and Levy; Hardaker and Tanago) provides an alternative means of reducing the number of portfolios to be considered. It is based on comparisons of cumulative distribution functions (CDFs) of alternative portfolios. We limit our discussion to first degree stochastic dominance (FSD) which is defined as follows: portfolio A with CDF $F(x)$ dominates portfolio B with CDF $G(x)$ by FSD if, and only if, $G(x) \geqslant F(x)$ for all x_i contained in the domain of x with strict inequality for at least one x_i. If FSD holds, then for any nondecreasing utility function, the decision maker would prefer the dominating portfolio.

In applying FSD to Scott and Baker's portfolios, the CDFs for portfolios X_6 through X_9 are sketched in figure 2 using the values in table 1. It is clear

Table 1. Income Results from Risk Programming Analysis for Selected Confidence Limits

Portfolio	$E - 1.96\sigma$ $\alpha = 0.025$	$E - \sigma$ $\alpha = 0.16$	Expected Income (E) $\alpha = 0.5$	$E + \sigma$ $\alpha = 0.84$	$E + 1.96\sigma$ $\alpha = 0.975$
	(1)	(2)	(3)	(4)	(5)
X_1	5,775	5,775	5,775	5,775	5,775
X_2	20,090	21,014	21,977	22,940	23,864
X_3	21,932	23,125	24,368	25,611	26,804
X_4	22,401	23,728	25,110	26,492	27,818
X_5	22,887	24,488	26,156	27,824	29,425
X_6	23,408	25,683	28,053	30,423	32,698
X_7	23,407	25,751	28,193	30,635	32,979
X_8	22,373	25,641	28,678	31,895	34,983
X_9	21,113	24,921	28,888	32,855	36,663

Source: Scott and Baker.

from comparing the row values for the respective confidence intervals in table 1 that the CDFs for X_1 through X_5 are dominated by X_6 and can be excluded from the analysis. Hence the choice remains among X_6, X_7, X_8, and X_9 which comprise the FSD efficient set.[2] Sequential analysis is applied to the FSD efficient set by supposing, as before, that the decision maker requires income from portfolios to exceed a threshold income of $22,000 by at least 97.5% probability. Thus, among those portfolios lying to the right of E-min on the 2.5% probability line, he will choose the one with the highest expected income—X_8 in this case.

FSD and Baumol's criterion will yield similar ordering of portfolios. While a rigorous proof of this similarity is beyond the scope of this comment, it can be shown that if portfolio A dominates portfolio B by FSD, then A will always dominate B by Baumol's

[2] Strictly interpreted, FSD cannot be applied to normal distributions since decreasing the lower confidence limit indefinitely would eventually result in the intersection of CDFs for E-V efficient portfolios. However, for this application, the lower ends of the distributions were arbitrarily truncated at the 2.5% probability level.

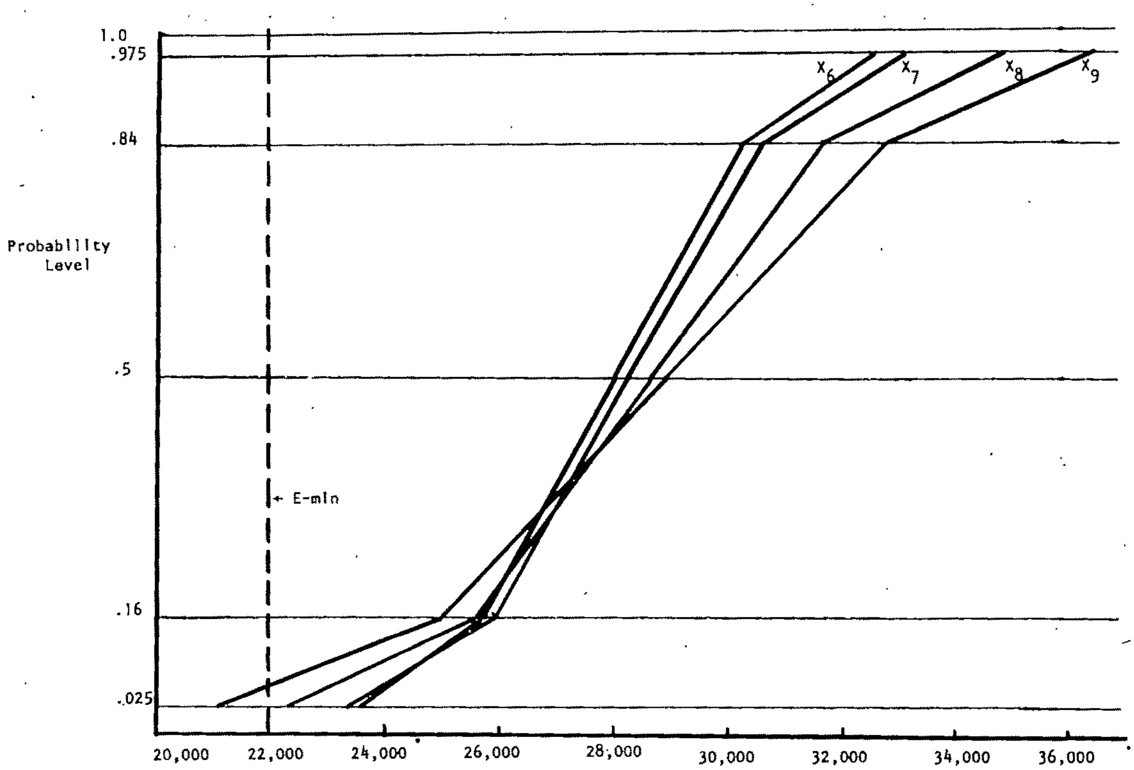

Figure 2. Cumulative density functions (CDFs) for FSD efficient portfolios

E-L criterion.[8] The similarity in results between FSD and *E-L* efficiency criteria is preserved when lexicographic utility analysis is applied to the efficient sets. An advantage of FSD is that the efficient set is not modified by the selection of lower confidence limits for threshold income, while for the *E-L* criterion, the number of efficient portfolios is a nondecreasing function of K.

We hope that this extension of Scott and Baker's analysis will facilitate the evaluation of risky information by decision makers, thereby improving their decisions and responses to managerial counsel. Moreover, these decision criteria can also be used to order portfolios characterized by distributions that need not be normal.

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[8] In lieu of a formal proof, an intuitive argument is offered. If portfolio A dominates B by FSD, then the expected value of A exceeds the expected value of B (see Hadar and Russell, p. 29; Hanoch and Levy, p. 338). Furthermore, since the CDF of A will never lie to the left of the CDF of B, the lower confidence limit for A will never be less than the lower confidence limit for B. Both of these conditions satisfy Baumol's requirements for *E-L* dominance of B by A. Thus FSD efficiency implies *E-L* efficiency regardless of the confidence level selected.

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MULTI-FREQUENCY COBWEB MODEL: DECOMPOSITION OF THE HOG CYCLE: COMMENT

ITSHAK BOROSH and HOVAV TALPAZ

In a recent article analyzing the decomposition of the U.S. Hog Cycle (Talpaz), a multi-frequency cobweb model was suggested as the economic mechanism behind this phenomenon. The cycle was considered as a combination of a few distinguishable cycles whose frequencies and amplitudes were estimated. Each cycle was of the form

$$(1)\quad P_n^*(t) = A_n^* \cos(n\omega_o t) + B_n^* \sin(n\omega_o t)$$

and

$$(2)\quad Q_n^*(t) = C_n^* \cos(n\omega_o t) + D_n^* \sin(n\omega_o t),$$

$$n = 0, 1, 2, \ldots,$$

where t denotes the time measured in months, $\frac{2\pi}{\omega_o}$ is the four-year (forty-eight months) period, $P_n^*(t)$ is the contribution to the hog-corn price ratio due to the nth cycle of period $\frac{2\pi}{n\omega_o}$, and $Q_n^*(t)$ is the contribution to the number of sows farrowed due to the nth cycle. For $n = 0$, equations (1) and (2) give the nonperiodic component of the price and quantity, respectively, and obviously A_o^* and C_o^* are nonzero.

In order to avoid arbitrariness in the selection of the units of measurement for prices and quantities, equations (1) and (2) are divided, respectively, by A_o^* and C_o^* yielding

$$(3)\quad P_n = P_n(t) = P_n^*(t)/A_o^* = A_n \cos(n\omega_o t) + B_n \sin(n\omega_o t)$$

and

$$(4)\quad Q_n = Q_n(t) = Q_n^*(t)/C_o^* = C_n \cos(n\omega_o t) + D_n \sin(n\omega_o t),$$

where $A_n = A_n^*/A_o^*$, and B_n, C_n, and D_n are defined similarly. Notice that equations (1) and (2) have been normalized by dividing them by the respective means for P and Q.

Now we discuss the locus of the point, $P_n(t)$, $Q_n(t)$, when t varies throughout an entire cycle. The equations (3) and (4) are solved for $\sin(n\omega_o t)$ and $\cos(n\omega_o t)$, and t is eliminated using the identity $\sin^2(n\omega_o t) + \cos^2(n\omega_o t) = 1$ yielding the equation of the locus.

If $A_nD_n - B_nC_n = 0$, equations (3) and (4) yield $D_nP_n = B_nQ_n$ which means that the locus degenerates to a straight line interval.

If $A_nD_n - B_nC_n \neq 0$, then $(A_nQ_n - P_nC_n)^2 + (D_nP_n - B_nQ_n)^2 = (A_nD_n - B_nC_n)^2$ which represents an ellipse. This ellipse will have its axes parallel to the P and Q axes if $A_nC_n + B_nD_n = 0$. In this case, the major axis will be parallel to the price axis if $A_n^2 + B_n^2 > C_n^2 + D_n^2$ and to the quantity axis if the inequality is reversed. In case of equality, the ellipse reduces to a circle. Larson's model, which implicitly assumes equality between price and quantity amplitudes, will always give a circle.

The direction in which the point (P_n, Q_n) describes its locus is determined as follows. Let θ be the directed angle pictured in figure 1. Then the sign of $d\theta/dt$ determines the direction of the motion—counterclockwise if $d\theta/dt > 0$ and clockwise if $d\theta/dt < 0$. From figure 1, $\theta = \tan^{-1}(P_n/Q_n)$, and therefore

$$(5)\quad \frac{d\theta}{dt} = \frac{\dot{P}_nQ_n - P_n\dot{Q}_n}{P_n^2 + Q_n^2} = \frac{n\omega_o(B_nC_n - A_nD_n)}{P_n^2 + Q_n^2},$$

where $\dot{P}_n$ and $\dot{Q}_n$ are derivatives with respect to time. Hence, the motion will be clockwise if $B_nC_n < A_nD_n$ and counterclockwise if the reverse inequality holds.

These results applied to the data contained in tables 1 and 2 of Talpaz show that all cycles except the one-year cycle are clockwise. The one-year cycle is counterclockwise. This cycle is also the only one whose axes are not parallel to the coordinates (Talpaz, fig. 9). Note that if the tolerance level, taken as the criteria for deleting the variables in the stepwise regression method described in Talpaz, would be raised, then these additional sine and cosine terms could slightly rotate the ellipse's axes. A clockwise motion is a well-known consequence of the cobweb theory, since the producers' decisions are based on current prices and there is a delay in production. Hence, the theory may explain the behavior of these cycles except the one-year cycle. Further interpretation can be achieved by using the price and quantity phase difference.

The delay between prices and quantities can be computed using the following considerations. Equations (3) and (4) can be written in the form

$$P_n = G_n \cos(n\omega_o t - \phi_n) = G_n \cos n\omega_o \left(t - \frac{\phi_n}{n\omega_o}\right)$$

and

$$Q_n = H_n \cos(n\omega_o t - \psi_n) = H_n \cos n\omega_o \left(t - \frac{\psi_n}{n\omega_o}\right),$$

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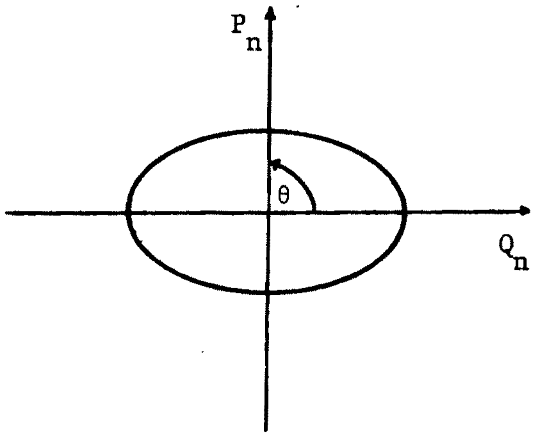

Figure 1.

where $G_n = \sqrt{A_n^2 + B_n^2}$ and $H_n = \sqrt{C_n^2 + D_n^2}$ are the price amplitude and quantity amplitude, respectively, and

$$(6) \quad \phi_n = \tan^{-1}(B_n/A_n), \psi_n = \tan^{-1}(D_n/C_n).$$

The value of $\delta_n = \frac{1}{n\omega_o}(\phi_n - \psi_n)$ can be interpreted as the delay (in months) between prices and quantities within the cycle. There is some ambiguity in computing δ_n from equation (6) since, for example, we cannot decide mathematically whether δ_n = three months in a one-year cycle, or δ_n = − nine months. It seems reasonable to resolve this ambiguity by taking $\delta_n > 0$ whenever the motion is clockwise and $\delta_n < 0$ if the motion is counterclockwise. From the data presented in tables 1 and 2 of Talpaz, it is found that the quantities lag one year after the prices in the four-year cycle and six months in the two-year cycle. In the one-year cycle, the prices lag eight and six-tenths months after the quantities. The counterclockwise motion of this cycle suggests that this cycle cannot be explained by the cobweb theory, and the fact that the quantities precede the prices by eight and six-tenths months can be explained by the production and distribution delays from farrowing to the consumer's purchase.

We hope these remarks will help in understanding the multiple frequency model of the hog cycle or similar phenomena. Furthermore, it shows that additional consideration of the time-series analysis, like the phase delay and the direction of motion within the cycle, may indeed contribute to a better analysis and understanding of fluctuating demands and supplies of various commodities.

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THE EXCHANGE RATE AND U.S. AGRICULTURE: COMMENT

THOMAS GRENNES

G. Edward Schuh has recently called attention to the relationship between currency exchange rates and agricultural prices. He emphasized that overvaluation of the dollar had depressed agricultural prices in the United States prior to 1971. However, the evidence presented by Schuh to show that the dollar was overvalued is unconvincing, and part of the price-depressing effects of overvaluation were probably shifted from American producers to foreign consumers.

He attributes the low agricultural prices prior to 1971 to overvaluation of the dollar and price increases since then to devaluation of the dollar. He measures overvaluation of the dollar by the liquidity definition of the balance of payments which showed a deficit for all but two years from 1950 to 1971. Since 1971 the dollar has depreciated by about 20% relative to an average of major currencies (trade-weighted dollar devaluation computed by Morgan Guaranty Trust and reported daily in the *Wall Street Journal*), but unfortunately Schuh's time series on the balance of payments stops at 1971. Since then the liquidity balance has remained in deficit in 1972, 1973, and the first two quarters of 1974 (U.S. Dept. of Commerce). Since the deficits of 1972 ($13.9 billion) and 1973 ($7.8 billion) were the largest in history (except for 1971), are we to infer that devaluation caused the dollar to become more overvalued than ever? If so, devaluation should have held agricultural prices down rather than raising them.

The dollar may have been overvalued before 1971, but the liquidity deficit was an unfortunate choice for an indicator of the excess demand for foreign exchange. Because of a secularly growing demand for dollars both by private foreigners and governments, the liquidity balance will be in deficit even when the foreign exchange market is in equilibrium (Kindleberger). More persuasive evidence of overvaluation exists, including Floyd's study of the dollar using the elasticity approach and Houthakker's estimate of overvaluation using purchasing power parity techniques. The most direct evidence of overvaluation is that under the current float, market forces have valued the dollar at nearly 20% less than in 1971. Schuh's main point about the dollar being overvalued is probably valid but his evidence is inappropriate.

Overvaluation of a currency is equivalent to a tax on all exports and a subsidy to all imports. What is the incidence of the implicit export tax? An export tax will lower the dollar prices of agricultural products to U.S. producers and consumers. If the United States has any monopoly power in export markets, the foreign currency price of agricultural products will rise, improving the U.S. terms of trade. Part of the export tax will be shifted from U.S. producers to foreign consumers, and in general, the larger the price increase abroad, the smaller the price decrease at home. Thus, exchange rate policy may alter the distribution of income between countries as well as between U.S. producers and consumers.

The importance of the terms-of-trade effect of overvaluation is an empirical question, and the market power of the United States as a buyer and seller in world markets is not negligible. Basevi's study of the entire U.S. tariff structure showed that the favorable terms-of-trade effects were so important that they dominated the losses due to production and consumption inefficiency. Houthakker and Magee's estimate of the foreign elasticity of demand for U.S. agricultural products of approximate unity implies considerable scope for raising foreign prices by restricting exports. Also, Johnson found that the favorable terms-of-trade effect of the U.S. tobacco program in the 1950s was nearly as large as the efficiency losses. To the extent that the overvalued dollar raised foreign agricultural prices, the tax burden of U.S. producers and landowners was reduced.

Finally, an offsetting factor must be considered. Many agricultural exports have been directly subsidized by the government (see Baldwin, p. 49). To the extent that the magnitude of the direct subsidies are positively correlated with the degree of overvaluation (implicit export tax) of the dollar, the two effects cancel and agricultural prices are not affected by exchange rate policy. A similar cancellation occurs when foreign tariffs are adjusted to offset U.S. devaluation, and the European Economic Community's system of variable levies may be an empirically important example of this kind of policy.

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THE EXCHANGE RATE AND U.S. AGRICULTURE: REPLY

G. EDWARD SCHUH

Before responding to Grennes' two main points about my paper, I would like to note that the assertion at the beginning of his second paragraph overstates the thrust of my paper by a considerable margin. In my concluding section I went to some length to put the analysis in perspective by stating that "the burden of the paper is not to argue that the over-valuation of the dollar was the only factor causing the farm problem, nor that the recent devaluations have been responsible for all recent increases in agricultural prices" (p. 12). I then listed some of the other factors that were responsible both for the secular decline of the 1950s and 1960s and the large and rapid increases of 1973. The basic premise of the paper was that the exchange rate had been an important omitted variable in past interpretations of U.S. agricultural development and trade problems, but that it was by no means the only variable at work.

Grennes states that the liquidity deficit was an unfortunate choice for an indicator of the excess demand for foreign exchange. The point has merit, and I would make no attempt to defend my choice over any other. Kindleberger, in the reference cited by Grennes, argues that no single number can be used and that at a minimum two measures should be considered, neither of which in his view is satisfactory. I provided data on both gold stocks and the balance of payments in part because no one measure is completely satisfactory. In addition, I wanted to show that there was at least presumptive evidence that the overvaluation had been persistent and had a tendency to grow larger in time.

Careful studies such as those by Floyd and Houthakker could have been cited, and perhaps I was remiss in not so doing. However, both studies refer to fairly short periods of time,[1] and it should be noted that neither the elasticity approach nor purchasing power parity techniques is without its critics. I agree with Grennes that the fact that market forces have valued the dollar at nearly 20% less than in 1971 is probably the most direct evidence of overvaluation in 1971. It is not particularly helpful in understanding what was going on in the decade of the 1950s.

In assessing empirically the consequences of the overvaluation it will be necessary to develop more precise estimates of the degree of overvaluation. Kindleberger's paper and the rather wide divergence between the estimates of Floyd and Houthakker suggest that it will not be an easy task, nor one that there will be general agreement on.

Secondly, Grennes asserts that there may have been terms-of-trade effects, and exchange rate policy may alter the distribution of income between countries as well as between U.S. producers and consumers.

The point is well taken, and I recognized it in my original article (pp. 11–12). In fact, in footnote 17 I went so far as to point out that unless offsetting measures are taken by countries which import U.S. agricultural products, incomes in those countries will be redistributed away from the landowners in those countries and toward their consumers.

I agree that the importance of the terms-of-trade effect of overvaluation is an empirical question. Unfortunately, the state of our econometric knowledge on basic demand and supply relations related to trade is still rather weak. Basevi himself points out that "most of the existing statistical estimates of demand elasticities for imports and exports are subject to severe downward bias, and estimates of elasticities of supply of exports and imports are practically nonexistent" (p. 849). Houthakker and Magee, in their much-cited study, express considerable reticence about their price elasticities, in part because of what they consider to be inadequate data.

If the foreign elasticity of demand for U.S. agricultural products was of the order of unity there would be considerable scope for raising foreign prices by restricting exports. However, the fact that we were willing to subsidize exports does not suggest that we thought there were gains to be had from restricting exports. Tobacco may at one time have been an exception, but it is also fair to note that it does not have close substitutes and that its demand elasticity is in fact low. My judgment, as noted in the original article, is that the foreign demand for most U.S. agricultural exports is rather elastic, but not perfectly elastic.

Moreover, Grennes notes that export subsidies may have compensated for the implicit export tax imposed by overvaluation of the dollar with the result that agricultural prices were not affected by exchange rate policy.

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[1] Houthakker's estimate refers to conditions as of March, 1962. However, he argues that the cause of the overvaluation of the dollar was the series of devaluations undertaken in September, 1949, which in the case of the pound sterling, the guilder, and other major currencies amounted to about 30%. He further argues that the true cost conditions remained hidden until the middle 1950s because Europe and Japan were still recovering from the war (p. 298).

Two points are worth noting. First, there is an incidence question with export subsidies also. The presumption is that export subsidies represent income transfers to the foreign consumer and not to the domestic producer. Second, in the period 1963–64 to 1972–73, the peak of the export subsidies was in the 1963–1964 fiscal year ($822 million) (U.S. Dept. of Agriculture). They tapered off after that and reached a low point of $64 million in 1968–69. The average export payments for 1970–71 and 1971–72 was $247 million. This does not suggest that there was much correlation between the magnitude of the subsidies and the degree of overvaluation. In fact, the interesting point is that export payments increased substantially in 1972–73, which was after the devaluations. This increase, of course, was largely for the Russian wheat deal.

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INFORMATION, POWER AND ACADEMIC RESPONSIBILITY: COMMENT

VERN ELEFSON

Randall's recent article, "Information, Power and Academic Responsibility," is a good contribution to the literature of the profession. Inevitably, however, it leaves some points untouched, one of which seems to deserve comment.

He strongly recommends the avoidance of impact distortion which he defines, "in the context of the scholarly provision of information, as the provision of more complete information about some aspects of a choice situation than others" (p. 231). It seems to me that, in a very fundamental sense, impact distortion cannot be avoided. (I do, however, recognize the possibility of reducing it.) Impact distortion results from the same factor that justifies economics as a field of study. It exists, unavoidably, because of a scarcity of resources. One cannot define a research project that is amenable to the complete investigation of every aspect, ramification, and implication of the central problem. Therefore, distortion must remain.

It is true that Randall's definition does not require absolutely complete investigation of all aspects—only equally complete. But this matter of equality is not subject to objective determination; it incorporates a host of value judgments. A person's concept of what constitutes equal information about different aspects of a problem is the result of as many factors as determine his opportunity set and power position. His decision, regarding whether a given aspect is either so relevant and immediate as to require equal treatment or so remote and insignificant as to allow him to disregard it, is subject to the same array of value judgments, power position influences, and coercive capacities.

To utilize Randall's example of the article by Schmitz and Seckler, even in the absence of quantifying research, American society has never held many illusions about the reality of technological unemployment. A ninety-year-old acquaintance tells me how his father prudently parked his first horse drawn reaper under his bedroom window as a safeguard against sabotage by his friends and neighbors who had customarily been hired to wield the scythe and cradle.

Agricultural economists did not investigate and quantify that and similar problems because the concensus of society at the time—at least the concensus as weighted by the power of society's elements—was that threatening unemployment should not stand in the way of "progress." Further, the rights to freedom in decision making on the part of an owner transcended any claim to employment on the part of labor. Therefore, questions about technological unemployment were irrelevant. The facts regarding such unemployment would have had little or no impact. It would have been a waste—an unacceptable waste of scarce resources to have pursued such research.

Today the consensus has changed. In particular, the values of society have changed. The current demand for research on the employment implications of a mechanical tomato harvester rests on two factors: (*a*) the desire to bolster, to explicate, to publicize, and to legitimate the shift in values, and (*b*) the desire for facts needed to effect changes that are dictated by the changed values.

Much of impact distortion is in the mind of the beholder, in the mind of the individual beholder and/or in the mind of society. The purveyor of information who wishes to avoid impact distortion, therefore, provides the kinds of information that his public wants. That is, essentially, what researchers have always done. The constraint of scarce resources forces them to limit the scope of their efforts and to do so in reasonable conformity to the wishes of society. No academician has an infinite opportunity set. Nevertheless, this is also the kind of behavior that can very easily be labeled impact distortive by an individual or group with new or different values.

Randall is careful to emphasize that scientific neutrality, including value neutrality and neutrality of impact, is not possible. A value neutral identification of much of what is considered impact distortion is equally impossible.

Scholars and their host institutions should attempt to avoid as much impact distortion as they can. This means that they should perform with as much fairness and propriety as they can within the social value system of their environment. But don't get caught up in guilt feelings occasioned by the idea that there is an approachable absolute standard of behavior that guarantees freedom from impact distortion. There isn't.

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INFORMATION, POWER AND ACADEMIC RESPONSIBILITY: REPLY

ALAN RANDALL

Given that Professor Elefson and I conclude that impact distortion in the context of the scholarly provision of information ought to be avoided to the extent feasible, a reply is perhaps unnecessary. However, the passage in Elefson's "Comment" leading up to and including the sentence, "the purveyor of information who wishes to avoid impact distortion, therefore, provides the kind of information that his public wants," invites rebuttal. The direction of scholarly efforts according to this precept exposes the profession to at least two dangers.

The scholar may define "his public" to be some specific subset of the general public. If so, following Elefson, he becomes a humble technician, serving a particular master or group of masters. This role is most nearly appropriate for the consultant. Yet, even the consultant finds the humble technician model inadequate. He must reserve the right to reject assignments which may oblige him to violate his moral or ethical values. The humble technician role is inappropriate for the scholar (Randall, p. 232).

Even if "his public" is defined broadly to mean the general public and all subsets thereof, the avoidance of impact distortion means something quite different from "tell them what they want to hear, about what they want to hear about." Even without a precise, objective, empirical specification of what is meant by zero impact distortion, we can apply the principle of "equally complete investigation of all aspects" (to quote Elefson's paraphrase of my definition) to conclude that sometimes the avoidance of impact distortion will necessitate telling them things they don't particularly want to hear, about things they would rather not hear about.[1] This is not necessarily a futile activity and a waste of scarce resources. Elefson underestimates the potential impact of information which is unhelpful to and thus unappreciated by powerful groups. The provision of such information itself contributes to the modification of power relationships and therefore to socioeconomic change (Randall, p. 233).

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[1] The avoidance of impact distortion is definable in principle but may not be amenable to objective empirical specification. However, this does not render it useless as a goal. Economists have made considerable analytical progress and have been effective and influential as purveyors of information, using criteria which are similarly inhospitable to objective empirical specification: efficiency and an equitable income distribution. If the avoidance of impact distortion is accepted in principle as a goal, considerable progress in that direction will be made.

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ON THE ISSUE OF MEMBERSHIP IN THE AAEA

A. BARRY CARR

Our past President, Kenneth Tefertiller, has invited suggestions on how the membership of the Association might be increased. This comment is a response to that invitation.

The subject of membership in a professional association might be viewed from either one or both of two distinctly different perspectives—that of the individual and that of the profession. To the extent that the content or concerns of the two perspectives coincide, all is well. The concerns of the individual may, however, conflict with or compete with the concerns of the group.[1] The stated objective of our Association is to further the development of systemic knowledge of agricultural economics, but this may not be the main concern of members or potential members.[2]

Some might suggest that agricultural economists ought to belong to AAEA simply because it is the professional thing to do. Yet the benefits of membership, the things the Association does for the member, seem meager. A member receives four regular issues of the *Journal* and a proceedings issue; a directory of members issued about once every six years; special announcements; and preregistration materials for meetings, special workshops, and symposia. He or she can use the employment service and vote for Association officers. A member is additionally eligible to receive travel grants and awards for professional excellence. Several items in the benefits list cannot be labeled strictly as "member benefits" since membership is not a requirement.

Each individual, operating within a micro-framework, decides annually whether or not he will invest another $15 in the Association. While many of the things the Association does are of value, the individual must determine the marginal value of obtaining these benefits directly as a member of AAEA versus acquiring them indirectly or even doing without them. For a substantial body of persons, this analysis results in their not becoming a member.

It seems that there are two principal means to increase membership in AAEA. The first might be to unbundle the present package of benefits. Evidently the subscription to the *Journal* represents a significant portion of the $15 dues. Many present and prospective members find a personal subscription to the *Journal* of little value.[3] A subscription fee could be charged those members who wish to receive the *Journal*, and the dues reduced accordingly for those who do not wish to receive it.

The second route to increased membership might be to increase the value of the benefits package offered to members. However, the success of an expanded membership service program is probably contingent upon the employment of a professional, full-time secretary for membership.[4] Management of

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[1] Even individuals may be separated into two groups, theoretical and applied. This is tacitly recognized within the Association by the distinction between academics and employees of government or industry. The problem is that by personal inclination the primary interest of some within government is more closely associated with the theoretical orientation of many academics, and the primary interest of some at academic institutions is more closely associated with the applied orientation of many in government or industry. A second problem is the tendency of those in one group to view those of the other group as something less than full-fledged professionals.

[2] The unfavorable image of the Association held by some practicing agricultural economists is perhaps an outgrowth of the narrow range of interests reflected by articles accepted for publication in the *Journal*. If *Journal* articles do not appear relevant to my work, membership in the Association does not appear to be relevant to my work.

[3] I do not believe that the report by Bruce Beattie from the questionnaire sent to AAEA membership refutes this conclusion. About 90% of those responding ranked the *Journal* as the first priority activity of the Association, but this was from a list of other activities in which the average member seldom participates (awards, workshops, and travel grants) or activities which are only available at additional cost (the *Bibliography*). Only 25% of the respondents approved of higher dues, while 44% preferred a page charge as a means of financing increased costs for publishing the *Journal*. In a similar vein, Harold Breimyer has reported that during his term as president more critiques and suggestions were received concerning the *Journal* than on any other subject.

[4] My proposal is really quite modest. By using existing facilities and support, the professional staff person could be financed for an added cost of about $40,000 a year. With the *Journal* converted to a subscription and page charge basis and with the expanded membership benefits package, dues of $10 and $5 for regular and student members, respectively, would be reasonable. Since only about $5 of a regular member's dues presently go for non-*Journal* activities, the proposed dues would result in additional non-*Journal* revenue of $14,000 from our present 2,800 regular members and $2,000 from our present 400 student members. The remainder to be financed from new memberships is $24,000. Our present student membership represents about 25% of the total graduate school enrollment in agricultural economics. An increase in the student membership to 50% of graduate enrollment would add 400 student members and $2,000. Can 2,200 additional regular members be found? I think so, based on the following observations. The lowest projection of Ph.D. degrees to be awarded in agricultural economics for the period

professional organizations is a profession unto itself and requires training and experience foreign to most agricultural economists. With appropriate revisions of the bylaws, this professional would become responsible for the day-to-day operation of the Association; the duties of the position would include membership solicitation, dues billing, and the arrangement of meetings. The contribution of this full-time executive would be further enhanced by the formation of local chapters of the Association through which he or she could work. These chapters would be geographically smaller than the present regional associations, which also seem to be experiencing declining membership. While they might be as large as one or two states, they would revolve around the area of largest membership, such as Washington or a land grant university location. Such a device is used effectively by many alumni associations and other special interest groups.

Among the new benefits which might ultimately be offered are advanced categories of membership or professional designations which might be earned by those wishing to establish their proficiency in the profession. These designations of accomplishment would become useful to employers and enhance the reputation of the Association in the eyes of other professions. A monthly newsletter or magazine, edited by the membership secretary and partially financed by advertisements, could be established for the purpose of announcing current activities, personnel changes, open positions, and employment sought. The membership directory should be issued yearly. As additional membership benefits are established, they could be placed into the regular dues package and made available to all, or designated as supplemental items which would only be available to members at cost.

One might sometimes wonder if professional associations, at least as we have known them, are an idea whose time has gone. Only 8% of our literature is published in journals (Littleton). Professionals no longer wait for the annual meeting to visit or confer with their colleagues. Many find it difficult to believe that their individual $15 membership or even the entire $125,000 budget of the Association can actually make a significant contribution to the "development of systemic knowledge of agricultural economics." We have to come up with an answer to the question of "What's in it for me?" Furthermore, we have to know what the questioner needs and wants before we can effectively answer his question.

1969–79 totals 2,160. Only 2% of the total number of agricultural economists need to be replaced each year because of death, retirement, or occupational change. During 1959–69, 1,241 Ph.D. degrees in agricultural economics were granted. NSF found that 58% of the agricultural economists they registered has a Ph.D. degree (Helmberger).

Thus, there were possibly 2,000 entrants to the profession in the last ten years, many of whom are obviously not numbered among the 2,800 current regular members. All of us, whether located in collegiate departments, government, or private industry, have numerous professional acquaintances who are generally considered to be agricultural economists, but are not AAEA members.

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A NOTE FROM THE EDITOR

WILLIAM G. TOMEK

The recent change in the editorship of the *Journal* makes this an appropriate time for the incoming editor to review editorial policy, to express some of his concerns, and to outline changes which are being made.

A statement of editorial policy appears inside the front cover of this issue. The statement has been shortened, but the basic policy remains unchanged. Our intent is to publish creative and scholarly papers —papers that clearly make a contribution to the literature of agricultural economics and allied subjects. Manuscripts may be theoretical or applied; they may address a policy issue or an unsettled question in methodology; they may relate to extension, research, or teaching. The *Journal* should reflect the professional activities of agricultural economists, including those from government, business, and universities.

Some topics, however, lend themselves to communication via a professional journal and others do not. A paper should have lasting relevance, but a paper may be relevant to a small or local audience while not so relevant to readers of this *Journal*. Moreover, some material is better conveyed by different formats, such as a monograph or book, while other material is better conveyed by different methods, such as audiovisual techniques. Manuscripts longer than forty-five double-spaced pages are discouraged. Indeed, most published articles contain twenty to thirty manuscript pages.

A minimum lag of six months exists between submission and publication; the usual lag is longer. Thus, with developments in rapid communication, the professional journal article may seem outdated. However, an article is something which can be read, studied, and underlined. A journal can be read at home, in the office, or on an airplane, and a journal collection provides a readily accessible store of knowledge.

Nonetheless, problems exist, not the least of which is the high cost of publication. Members of the AAEA have also expressed concern about the usefulness of the *Journal* (Smith). Some think that articles are too mathematical and are not adequate discussions of the policy implications of empirical research. In my judgment, a careful reading of the *Journal* indicates that these views are exaggerated. Numerous articles contain no algebra, and many have a policy orientation. Most manuscripts undergo extensive revision during the review procedure, and authors are often asked to elaborate on the policy implications of their work. For example, I would consider unpublishable a manuscript consisting of a conventional econometric analysis without an application of the results to a policy or methodological question.

A concern of the editor is the recent lack of papers which either have broad applications (e.g., Nerlove) or which explore the usefulness of new techniques for practical problems (e.g., Waugh). Agricultural economists were the first economists to make use of advanced methods of mathematical statistics (Leontief, p. 5), but I doubt that our profession is maintaining its leadership in exploring and appraising new models and techniques.

Another, more practical concern of the editor is the number of first drafts and unpolished papers submitted. Authors should have their manuscripts critically reviewed by colleagues prior to submission. Manuscripts which are poorly written will be returned to the author without review.

Several changes in editorial policy have an immediate effect on authors. The reference system has been changed so as to place names, rather than numbers, in the text. The name provides the reader with more information than a number, and the new reference system also contributes to the simplicity of the *Journal's* style. All authors should use the new reference system. Instructions for submitting manuscripts are provided inside the back cover.

Authors' names will be deleted from manuscripts before being sent to reviewers.[1] The anonymity of an author apparently has little or no effect on his manuscript's reception (Borts, p. 478). However, authors seem to prefer the system, and the procedure adds relatively little to the costs of running the editorial office. Authors can help the editors by typing the title and their name on a separate title page which can be removed from the manuscript. The title should be repeated on the first page of the text. Obviously authors should avoid identifying themselves in the text.

To simplify the *Journal*, some modest changes have been made in its style. Fewer kinds of type are used, and headings are left-justified rather than centered. Contributions are classified either as "articles" or "notes" depending on their length and content. A note is a short paper on a specific topic, such as an

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The editorial policy statement and this note benefited from discussions with the Editorial Council, the Book Review Editor, and the editorial staff in Ithaca. I am responsible for the final content.

[1] In the Smith Committee report, a few individuals indicated a lack of familiarity with the *Journal's* review procedures. While this is not the place to describe such details, authors may write for a copy of the instructions sent to referees of manuscripts, and the editor is willing to respond to questions about review procedures.

extension of previous research, a comment, a reply, or other commentary. Notes are not inferior articles.

The various changes tend to make life easier for the editors and the printer, and we think they will benefit both authors and readers. I hope you find the *Journal* attractive and readable.

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Publications

BOOKS REVIEWED

Berger, Peter L., Brigitte Berger, and Hensfried Kellner. *The Homeless Mind: Modernization and Consciousness.* New York: Vintage Books, 1974, x + 258 pp., $1.95 paper.

This book presents a study of the consciousness structures associated with the institutions and institutional processes ascribed to modernity. It will prove useful for economists and social scientists interested in development, economic systems, industrial organization, urban economics, etc. Consciousness is studied from the perspective of the sociology of knowledge and according to the classical tradition of sociology (e.g., E. Durkheim, F. Töennies, M. Weber, T. Parsons, and M. Levy). The book is organized in three major parts. The first one describes modern consciousness as it is presently developed in advanced industrial societies (e.g., North America, USSR, and Western and Eastern Europe). The global effect of modernity is described as one of "homelessness." The other two parts of the book describe processes now developing in relation to modernity. The second part describes the modernization process taking place in the Third World (Asia, Africa, and Latin America), the collisions of consciousness that it generates, and the countermodernization movements. The third part describes the reactions against modernization within advanced industrial societies and the new process of demodernization as a quest for new ways of "being at home" in society like the community movements in the youth culture.

The description of the fields of consciousness is done in terms of the organization of knowledge (content) and cognitive styles (mode) associated with the major modern institutions. Modernization in advanced industrial societies and its transmission to the Third World are analyzed in terms of packages (empirical linkages of institutional processes and clusters of consciousness) and carriers (institutional processes or groups that produce or transmit particular elements of consciousness). Part of the authors' concern is to distinguish between packages that are intrinsically necessary to modernity and those which are not.

First part—modern consciousness. The two major institutions or primary carriers of modernity are technological production (chap. 1) and bureaucracy (chap. 2). A secondary carrier is pluralization of social-life worlds (chap. 3). The authors thoroughly describe the intrinsic organization of knowledge of and cognitive styles corresponding to these primary carriers, the particular relations among individuals and between the individual and himself brought about by these institutions (i.e., the anonymous social relations and self-anonimization generated by technological production as well as the social moralized anonymity and the disidentification between the individual and his manipulative role generated by political bureaucracy), and the development of a "human engineering" as a necessity of these two institutions and the subjective life of individuals.

Pluralization of the social-life worlds is expressed in the dichotomy of public and private spheres and the fragmentation of the private sphere itself. The socialization processes of pluralization are studied as well as their associated organization of knowledge and cognitive style leading to the concept of long run planning of family activities.

Chapter 4 turns into the most difficult task of explaining the institutional determinants of modern consciousness. The authors identify themselves with the Weberian sociological approach for which a causal reciprocity exists between institutional process and process of the level of consciousness. Nevertheless, the book concentrates on the effect of modern institutions on the development of modern consciousness. The two basic hypotheses of the authors are: (*a*) there are more intrinsic linkages between institutional processes and clusters of consciousness in the case of primary carriers than in the case of other carriers, and (*b*) as between the primary carriers themselves, there are more intrinsic linkages between institutional processes and clusters of consciousness in the case of technological production than in the case of bureaucracy.

Second part—modernization. This part describes the institutional modes by which modernization is carried over into the third world today. It is a notable overcomprehensive description. However, it is molded by the authors' sociological approach (with heavy doses of functionalism).

Modernization in the third world presents itself as a process of Westernization. Technological economy and political bureaucracy are also the primary carriers of modernization. But in many politically independent countries, the bureaucratic states become

the main mobilizing agents for development, and socialism presents itself as the more attractive model.

With modernity, the world is redefined with others reclassified, and anomie takes place at the level of the self. The major ideological responses to modernization are: the endorsement of modernization (e.g., developmentalism); next, the countermodernization ideology (e.g., nativism); and third, the ideologies that seek to maintain or to revitalize an indigenous tradition in the face of modernization (e.g., traditionalism). But most recently the notion of controlled development has been developing. These ideologies are called postmodernism and are exemplified by Ivan Illich's ideas of education, convivial society, and cultural revolution and by Paulo Freire's "conscientization."

Third part—demodernization. This part describes the discontent with modernity in advanced industrial societies. It will prove useful for the positivistically oriented minds who resisted the more analogical and holistic interpretations of Charles Reich.

The reasons for today's discontent with modernity are (*a*) the intensification and acceleration of technological and democratic processes as well as urbanization, and (*b*) the peculiarly modern transformation in the biographical stages of childhood (sheltered, tender, and "sentimental") and youth (lengthening of schooling which expands the stage of youth). Demodernizing movements proclaim that the individual is to be liberated from individualism to the solidarity of either old or new collective structures. Youth culture and counterculture are described as embodiments of demodernizing consciousness.

The authors assert that necessary intrinsic and extrinsic limits to any demodernizing enterprise will condemn it to be parasitical upon the structures of modernity. Its existence will depend on the tolerance of the larger society and to a larger degree on subsidization by an affluent society. However, they recognize the possibility that the youth and counterculture will have modifying effects on the overall culture—a "greening" effect, a pluralization of education allowing for other goals than technological and bureaucratic training and careers outside the technological-bureaucratic structure.

Conclusion—political possibilities. The authors try to close the book with a discussion of the political implications of the analysis. However, they conclude with neither obvious nor unambiguous considerations of the social scientists' roles.

Overall, this book is a well-done description of modern consciousness within the functionalist approach of classical sociology. It does not explain satisfactorily what most functionalists do not explain —the dynamic interrelations between institutions and consciousness in the long run. In the background of the authors is the idea of a social equilibrium—a steady social state—which society tends to. Philosophy of history is typically inimical to functionalism in sociology. This may explain why the authors do not include a discussion of the dialectic between "advanced industrial societies" and the third world which is taking place both at the institutional (in the sense of classical sociology) and conscious levels. By disregarding the theory of dependence, which sees modernization as a linkage between central capitalism and peripherical capitalism, they are unable to foresee the drastic stoppage in the development of technological economy that may take place in advanced societies as third world countries undertake the economic administration of their natural resources and primary products. By factoring out other clusters of consciousness under the concept of "traditional patterns," they do not notice the development of deeper perceptive functions that were only possible in societies where feelings were not suppressed. They are the ones which are permeating youth cultures in advanced societies thanks, of course, to modern communication media and greater mobility. The authors may be correct in being cautious in the evaluation of how deep the effect of the new spiritual movements at the level of the whole society or even on the youth culture is. This was the same precaution of Jacob Needelman in *The New Religions*.

Nevertheless, the authors are in sympathy with the theme of participation which permeates the social and individual liberating experiences around the planet. They foresee socialism as an institutional form to bring man "at home." This is in correspondence with the ideas of the cultural or economic necessity of socialism in the United States of Michael Harrington and John K. Galbraith.

A final comment. A study about consciousness and reality will expand the understanding of mankind's prospects if it is recognized that one of man's quests is not only to establish (modernization) or change (counter- or demodernization) fields of consciousness (organization of knowledge and cognitive styles), but also to transform (deepening) states of consciousness, i.e., to migrate into participating inner spaces where those fields are. But to be fair, one should not expect a sociological study to deal with the liberating experiences that a few "contemporaneous men of the future" are embracing around the whole planet. Still, anthropologists and psychologists are leading sociologists and economists in the scientific study of consciousness.

Carlos Benito
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Leed, Theodore W., and Gene A. Garman. *Food Merchandising, Principles and Practices.* New York: Chain Store Age Books, 1973, 389 pp., $9.95.

Food merchandising, as explored in this book, focuses primarily on the retail store, but more specifically on the supermarket in the United States. The development of modern stores and their practices is outlined, as well as the shift from bulk commodities to branded products at retail. Consumer demand aspects include price elasticity, marginal utility, cross elasticity and income elasticity. Objectives of retail organizations under varying geographical and competitive conditions and strategies for attaining these objectives are discussed.

The buying function for stores outlines major considerations when considering size and frequency of ordering at both the wholesale and retail level. Information is presented on computerized programs, such as COSMOS and CLIM, for planning and control purposes.

Two excellent sections on pricing at retail include techniques and information useful to those who would understand price competition at the retail—consumer interface. This includes some discussion of break-even analysis, variable margin pricing of individual products and operating departments, as well as pricing strategies of both conventional and nonconventional food stores.

The use of advertising and promotions by processors and manufacturers to retailers is explored, as well as advertising and promotion used by retailers to achieve their sales and profit objectives. Other topics include display principles and practices, store layout considerations, profit planning and control, regulations affecting food merchandising and merchandising trends for the future.

Limited information is presented on personnel training, motivation and rewards, or other aspects of the people equation of food merchandisers. There is virtually no exposition of financial requirements or of structural considerations that can have a major bearing on retail planning and operations. There is little consideration of horizontal and vertical integration as an influence on those responsible for merchandising decisions in the channels of trade and at retail. The impact of manufacturers, processors, brokers, wholesalers, rack jobbers, and labor unions is briefly treated with little assessment of the impact of these organizations and institutions on retail merchandising practices.

The authors do a commendable job of focusing on the planning and achieving of merchandising objectives, on consideration of consumer satisfaction, and on crucial merchandising decisions by those responsible for retail operations in a competitive environment.

This book can be recommended to those who wish to understand food retailing today. It would also be useful as a text in a basic food retailing course. Furthermore, it has value as supplementary reading for agricultural marketing courses, which may need to focus on this final step in our food production and marketing process.

Edgar P. Watkins
Ohio State University

Mäler, Karl-Goran. *Environmental Economics: A Theoretical Inquiry.* Baltimore and London: The Johns Hopkins University Press for Resources for the Future, 1974, x + 267 pp., $15.00.

Seneca, Joseph J., and Michael Taussig. *Environmental Economics.* Englewood Cliffs: Prentice-Hall, 1974, xi + 354 pp., $10.95.

These two books help fill a large void in environmental economics. Both books address themselves to similar environmental issues but from quite different viewpoints. Mäler utilizes a mathematically rigorous and highly theoretical approach to incorporating environmental quality into general equilibrium theory. Seneca and Taussig utilize a much less sophisticated theoretical approach but attempt to blend economic theory with environmental facts and social circumstances. They rely heavily upon the application of the standard benefit-cost or efficiency criteria of economics to a wide variety of environmental problems.

The book by Mäler consists of six chapters each from forty to fifty pages in length with the exception of the more brief first chapter. Chapter 1 includes a brief review of economists' views on environmental problems and a preview of the remaining five chapters. A simple materials-balance, general-equilibrium framework which provides the foundation for the remainder of the book is presented.

In chapter 2 Mäler constructs a general equilibrium model which entails environmental quality. Production possibilities include consumption goods and services, intermediary commodities, raw materials, residuals, and environmental services. Consumers derive satisfaction from consumption processes that involve consumption goods and services, and environmental services and the consumption processes generate residuals. Environmental services are public goods whose supply is assumed to be controlled by a special environmental management agency. In a rigorous manner the existence of an equilibrium is proved and the relations between an equilibrium and an optimum are developed. The

chapter closes with some interpretations and generalizations of the model.

Chapter 3 focuses on the relations between economic growth and environmental quality. Four paradigms including an economy with one composite good which may be used either for capital accumulation or consumption and three inputs, capital, labor and natural resources, are considered. The first paradigm entails a single deposit, finite amount and homogeneous quality, of a nonrenewable resource. In the second paradigm different qualities of natural resources are introduced. In the third paradigm population is permitted to change and in the fourth paradigm the recycling of materials is introduced.

Chapter 4 provides the reader with a rigorous and comprehensive treatment of consumption theory when residuals of consumption activities and public goods such as environmental services are considered. The latter parts of this chapter focus on consumers' surplus and some selected aspects of social welfare functions.

Alternative approaches for estimating the demand for environmetal services for which no markets exist are discussed in chapter 5. Selected problems in environmental policy such as effluent charges, effluent standards, random waste loads, trial and error processes, and impacts on income distribution are analyzed from a theoretical viewpoint in the final chapter, chapter 6.

The book by Mäler is a scholarly attempt to develop an economic theory framework which includes environmental quality. The theoretical insights should be of interest to environmental and mathematical economists, welfare theorists, and quantitatively oriented people in public finance. The book is strictly theoretically oriented and void of any empirical applications. To appreciate the contributions of this work the reader needs to have a good background in economic theory, particularly micro theory and mathematics.

The book by Seneca and Taussig is analysis oriented and attempts to use economic tools in analyzing a wide variety of environmental problems. The benefit-cost framework is the "backbone" of this book. Throughout the book the authors support the economic concepts with empirical evidence.

Environmental Economics consists of five parts. Part I consists of one chapter which outlines the book, attempts to put environmental problems in perspective, and introduces the cost-benefit approach to environmental problems.

The basic theory of environmental economics is presented in part II which consists of four chapters, 2–5. In chapter 2, the basic principles of welfare economics are reviewed and the connection between the working of a private market economy and the concept of efficiency is established. Externalities and their significance with regard to efficiency of resource allocation are presented in chapter 3. Chapter 4 focuses on property rights, common property resource problems, and alternative solutions to the externalities problem. In chapter 5 the concept of public goods is developed and applied to problems of environmental quality.

Part III, consisting of chapters 6–9, focuses on the economic issues of selected environmental problems. The empirical evidence supporting concepts such as benefits, costs, and externalities is emphasized in this part. Issues related to water quality problems are presented in chapter 6, while details of factors responsible for the deterioration of air quality are discussed in chapter 7. Chapter 8 addresses itself to environmental problems related to pesticide use, solid wastes, noise, outdoor recreation, and land use as important aspects of quality of life.

Part IV consists of chapters 9–11 and is concerned with the various vehicles of collective environmental action. Regulation and prohibition are analyzed in chapter 9, and taxes, subsidies, and effluent charges are considered in chapter 10. The efficiency and equity problems of governmental production of environmental services are discussed in chapter 11.

Part V consists of three chapters which attempt to link population, economic growth, and environmental quality. The role of the population level in determining environmental quality is discussed in chapter 12. The linkages between urbanization and environmental quality are presented in chapter 13. Chapter 14, the final chapter of the book, focuses on the relationship between economic growth and environmental quality. The last section of this chapter briefly mentions some of the research needs in environmental economics.

The book by Seneca and Taussig should be of interest to individuals concerned with resource and environmental problems, environmental regulation, public finance, and welfare economics. The blend of economic theory and empirical application should appeal to a wide audience. This book should serve well as a text for an undergraduate or dual level, undergraduate-graduate, course in environmental economics and might also serve as a useful supplementary text for an undergraduate or dual level course in resource economics.

Joseph Havlicek
Virginia Polytechnic Institute and State University

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News

ANNOUNCEMENTS

ANNUAL MEETING, 1975

The annual meeting of the American Agricultural Economics Association will be held August 10–13 at Ohio State University in Columbus, Ohio. Correspondence concerning the meeting should be directed to the local arrangements chairman, Dr. Francis B. McCormick, Department of Agricultural Economics and Rural Sociology, Ohio State University, Columbus, Ohio 43210. More detailed information on the meeting will be published in the May issue.

VISITING LECTURER PROGRAM

The American Agricultural Economics Association is again conducting a Visiting Lecturer program for 1975. The Visiting Lecturer program is limited to those universities offering an undergraduate or master's degree, but not a Ph.D. degree. Since Association funds are not available to support the program, attempts are made to match the desire for a particular individual to give a lecture with the availability of that person to travel to the university.

The procedure works best where the college or university selects three or four specific agricultural economists they would like to have visit their school. The chairman contacts the selected individuals to see if they are available to give the requested lecture. Generally, dates are negotiated directly between the lecturer and the school from that point.

The chairman would be very happy to receive requests. Send the requests to R. J. Hildreth, Farm Foundation, 600 South Michigan Avenue, Chicago, Illinois 60605.

ECONOMICS INSTITUTE

The Economics Institute announces the eighteenth session of its summer program to be held in Boulder, Colorado, May 29–August 20, 1975. The program is designed for international students who are coming to the United States to undertake graduate studies in economics and related fields, including agricultural economics, management, and business. Participants will have an opportunity to review and strengthen their academic preparation and English proficiency through intensive instruction adjusted to their individual needs. The Institute is sponsored by the American Economic Association and is conducted in cooperation with admitting universities and student sponsoring agencies. For further information write: Director, Economics Institute, University of Colorado, Boulder, Colorado 80302.

NAME CHANGES

The name of the Department of Agricultural and Food Economics at the University of Massachusetts, Amherst has been officially changed to the Department of Food and Resource Economics.

The name of the graduate degrees conferred by Montana State University's Department of Agricultural Economics and Economics has been changed from Ph.D. and M.S. in Agricultural Economics to Ph.D. and M.S. in Applied Economics.

PERSONNEL

AGRICULTURE CANADA

Appointment: Robert L. Christensen, on leave as professor of food and resource economics at the University of Massachusetts, is with the Research Division, Economics Branch.

AUBURN UNIVERSITY

Appointment: John L. Adrian, Ph.D. University of Tennessee, is an assistant professor of resource and quantitative economics.

CLEMSON UNIVERSITY

Appointment: J. Edwin Faris, former chairman of the Department of Agricultural Economics at Washington State University, is the chairman of the Department of Agricultural Economics and Rural Sociology.

CORNELL UNIVERSITY

Appointments: Wallace E. Tyner is a research associate; **Lee Day** is the director designate of the Northeast Regional Center for Rural Development; **Herrell F. DeGraff** is a senior lecturer; **W. Keith Bryant,** former professor of agricultural and applied economics at the University of Minnesota, is a professor at the New York State College of Human Ecology.

UNIVERSITY OF GUELPH

Appointments: Donald MacLaren, University of Aberdeen, is a visiting professor of agricultural policy and price analysis from January to August, 1975; **P. A. Wright** is chief of the Agricultural Economics Section; **W. M. Braithwaite** is chief of the Agricultural Business Section; **H. W. Caldwell** is chief of the Extension Education and Rural Development Section.

Leave: R. S. Rodd is spending six months at the University of London studying British regional planning methods, beginning January 31, 1975.

UNIVERSITY OF KENTUCKY

Appointments: Joe T. Davis, Ph.D. University of Tennessee, is an assistant professor of livestock marketing; **David L. Debertin,** Ph.D. Purdue University, is an assistant professor of production-natural resources; **Charles L. Moore,** Ph.D. Ohio State University, is an assistant extension professor of farm management.

Return: Russell H. Brannon, professor, is back after three years in Kohn Kaen, Thailand as chief of the Kentucky/AID team.

Retirement: Carl M. Clark, associate professor, has left after thirty-seven years of service.

UNIVERSITY OF MANITOBA

Honor: Om P. Tangri, professor of agricultural economics and farm management, has received the University of Manitoba Graduate Students' Association Award for Excellence in Graduate Teaching.

UNIVERSITY OF MINNESOTA

Appointments: Fred J. Benson, Ph.D. University of Missouri, is an associate professor and extension economist in farm management; **Raymond J. Brady,** M.S. University of Arizona, is a research specialist; **Maury E. Bredahl,** Ph.D. candidate University of Minnesota, is a research associate; **Yigal Danin,** Ph.D. Hebrew University of Jerusalem, is a postdoctoral fellow; **Ronald J. Dorf,** Ph.D. Kansas State University, is a research associate; **Gordon D. Rose,** Ph.D. Iowa State University, is a professor and director of the Community and Research Development, Agricultural Extension Service; **John W. Schamper,** Ph.D. University of Wisconsin, is an assistant professor and a member of the Minnesota team in Tunisia; **Benjamin H. Sexauer, Jr.,** Ph.D. Stanford University, is an assistant professor; **Jerry L. Thompson,** Ph.D. candidate University of Minnesota, is an instructor; **Cameron S. Thraen,** M.S. South Dakota State University, is a research specialist; **Peter G. Warr,** Ph.D. Stanford University, is a postdoctoral fellow; **John J. Waelti** is part-time acting director of the Water Resources Research Center, effective October 1, 1974.

Return: Terry L. Roe, associate professor, is back after a two-year assignment in Tunisia with the Minnesota-Tunisia project.

MISSISSIPPI STATE UNIVERSITY

Appointment: Robert J. Martin, Ph.D. Virginia Polytechnic Institute and State University, is an assistant professor.

UNIVERSITY OF MISSOURI

Appointment: Norlin A. Hein, Ph.D. University of Minnesota, is an extension economist in farm management.

MONTANA STATE UNIVERSITY

Appointment: Mary E. Ryan, assistant professor at the University of Minnesota, is with the Depart-

AID: Agency for International Development; CED: Commodity Economics Division of ERS; ERS: Economic Research Service of USDA; FDCD: Foreign Demand and Competition Division of ERS; FDD: Foreign Development Division of ERS; NEAD: National Economic Analysis Division of ERS; NRED: Natural Resource Economics Division of ERS.

ment of Agricultural Economics and Economics for 1974–75.

UNIVERSITY OF NEBRASKA

Honors: Ronald Hanson was recently accepted as a member of the Nebraska Society of Farm Managers and Rural Appraisers; **James G. Kendrick** was the 1974 recipient of the Nebraska Agricultural Youth Institute Award of Merit.

OHIO STATE UNIVERSITY

Appointment: Allan Lines, Ph.D. Purdue University, is an assistant professor of farm management.
Leave: Richard Duvick is spending from August 1974 to February 1976 in Seoul, Korea working on the Michigan State University Korean Subcontract with Ohio State.

OREGON STATE UNIVERSITY

Appointments: Gordon C. Bjork is professor of economics and agricultural economics for 1974–75; **Paul W. Barkley,** on leave from the Department of Agricultural Economics at Washington State University, is a visiting professor in the Department of Agricultural Economics.

PURDUE UNIVERSITY

Appointments: Michael B. Sands is an assistant professor of agricultural economics, livestock marketing; **David L. Darling, Jr.** is a temporary instructor of agricultural economics, rural development; **Darrel Plaunt** is a visiting professor of agricultural economics, quantitative methods; **George G. Judge** is a part-time visiting professor of agricultural economics, quantitative methods.
Honor: Emerson M. Babb is serving as chairman of the Faculty Senate for 1974–75.

RUTGERS UNIVERSITY

Appointment: Dennis J. Palmini, Ph.D. University of Illinois, is an assistant professor in the Department of Agricultural Economics and Marketing, Cook College.

SOUTHERN ILLINOIS UNIVERSITY

Appointment: Vincent Cusumono, Ph.D. University of Kentucky, is with the agricultural industries staff and the UNDPFAO contract team at Santa Maria, Brazil.

STANFORD UNIVERSITY, FOOD RESEARCH INSTITUTE

Appointments: Dale Adams, on leave as professor at Ohio State University, is a visiting professor for 1974–75 working on the Korean Farm Level Savings Consumption Project; **Keith Acheson,** associate professor at Carleton University, is a visiting scholar for 1974–75; **Raymond E. Borton,** on leave from the Agricultural Development Council in the Philippines, is a visiting scholar for 1974–75; **Dennis L. Chinn,** Ph.D. University of California, Berkeley, is an assistant professor.

TEXAS TECH UNIVERSITY

Appointment: James E. Osborn, assistant dean of the College of Agricultural Sciences in charge of research coordination, is chairman of the Department of Agricultural Economics.
Resignation: Mark L. Fowler has vacated his position as chairman of the Department of Agricultural Economics and returned to full-time teaching and research in the department.

USDA

Appointments: Walter L. Fishel, on leave as associate professor at the University of Minnesota, is spending his second year at the Agricultural Research Service, Beltsville, Maryland; **Richard A. Greenhalgh,** formerly with ERS at the University of Missouri, is an agricultural economist at the University of Florida; **O. Wendell Holmes,** former secretary of the Western Agricultural Economics Research Council at Oregon State University, is executive secretary of the Great Plains Agricultural Council at the University of Nebraska.
Appointments in CED: George Allen, Bob Butel, Gail Garst, Robert S. Golden, Richard Haidacher, William Hall, John K. Hanes, Rodney Kite, Duane L. Marquis, Jimmy Mathews, Jim Miller, James E. Nix, Gerald O'Mara, and **Allan Walter** are working in Washington, D.C.; **Milton Ericksen, Ronald Krenz,** and **Charles Michael** are at Oklahoma State University; **Bill Bolton** is at Louisiana State University; **Ernst Smith** is at the University of Florida; **Arthur Womack** is at the University of Minnesota.
Appointments in FDCD: Sally Breedlove, Miles Lambert, and **Sharon Webster** are working in Washington, D.C.
Appointments in NEAD: Mary Bailey, Richard O. Been, Conrad F. Fritsch, Gerald E. Grinnell, Elwin E. Guild, Christine J. Hager, Charles Sisson, R. Thomas Van Arsdall, and **Chung-Jeh Yeh** are working in Washington, D.C.; **John H. Berry** is the deputy director in Washington, D.C.; **Clifford Carman,** formerly in Washington, D.C., is at Oklahoma State University; **J. Gerald Foster** is on a special assignment in Spain; **J. B. Penn,** formerly at Purdue University, is at North Carolina State University.
Appointments in NRED: Richard Carkner, formerly at Michigan State University, is at North Dakota State University; **A. R. Miller** is at the University of Nebraska; **Arnold Miller** is at Michigan State University; **Melvin Skold** is at Colorado State University.
Resignations and Retirements: Warren R. Bailey, Zolon Looney, and **Nobel Veal** have left CED; **George E. Dudley** has left NEAD to join the legal profession in Virginia; **William A. Green, Walter Gensurowsky, Michael Prince,** and **Joseph Vasien-**

ich have left NRED; **John Muehlbeier,** former executive secretary of the Great Plains Agricultural Council at the University of Nebraska, has left after forty years of federal service.
Award: George Rogers, CED, received the USDA Superior Service Award for Outstanding Leadership for developing and conducting economic research in the poultry industry.
Foreign Assignments: Ed Farstad represented agriculture in Middle East talks led by Treasury Secretary William E. Simon recently. The delegation visited the United Arab Republic, Saudi Arabia, and Israel.

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Appointments: William L. Brant, formerly at Oklahoma State University, is a professor and farm management extension leader; **Ewen M. Wilson,** formerly at the University of Rhodesia, is an assistant professor of marketing extension; **R. McFall Lamm, Jr.,** M.A. North Carolina State University, is a research associate.

WASHINGTON STATE UNIVERSITY

Appointment: LeRoy F. Rogers is the new chairman of the Department of Agricultural Economics; **William Pietsch,** formerly with NRED in Denver, is now with the Department of Agricultural Economics.

UNIVERSITY OF WISCONSIN

Appointment: Hiroshi Yamauchi, University of Hawaii, is an adjunct professor in the Department of Agricultural Economics for 1974–75.
Honor: Frank Groves was elected trustee of the American Institute of Cooperation at their Annual Institute.

OTHER APPOINTMENTS:

Kurt R. Anschel, on leave as a professor at the University of Kentucky, is with the Division of Economics and Sector Planning, Technical Assistance Bureau, AID.
Joe Blake, formerly with NEAD, is with the Commodity Exchange Authority.
Gail L. Cramer, on leave from Montana State University, is a visiting professor at the Harvard School of Business.
Lynn M. Daft, former assistant deputy administrator of ERS, is with the Office of Management and Budget.
William D. Eickhoff is the associate director of agricultural research at the Cotton Incorporated Research Center, Raleigh, North Carolina.
Gar Forsht, formerly with NRED, is with the Food and Nutrition Service, Washington, D.C.
Don Frahm, formerly at the University of Nebraska, is with Cook Industries in Memphis, Tennessee.
Gene Harris, formerly with NRED at the University of Florida, is with Cook Industries, in Memphis, Tennessee.
Ron Hendrickson, formerly an extension economist at Washington State University, is with Prudential Insurance Company in Pasco, Washington.
Richard Johnson, formerly with NRED at Michigan State University, is with the National Park Service.
R. M. A. Loyns, professor of agricultural economics and farm management at the University of Manitoba, is assistant deputy minister, Department of Consumer and Corporate Affairs, Policy Analysis Group.
Lowell A. Lumpkin, M.S. Purdue University, is operations research assistant, Land O' Lakes, Incorporated, Minneapolis.
Benton F. Massell, formerly a professor at Stanford University Food Research Institute, is with the Office of Management and Budget, Executive Office of the President, Washington, D.C.
Earl Oehlschlaeger, formerly with ERS, is at Spokane Community College, Spokane, Washington.
Evonir Batista de Oliveira, Ph.D. Purdue University, is economic advisor to the Minister, Ministerio da Agricultura, Brasilia, Brazil.
Douglas M. Paquin, formerly with NEAD, is with the Federal Energy Office.
Hans Peterson, former visiting assistant professor at the University of Wisconsin, is with AID.
G. Edward Schuh, on leave from Purdue University, is a senior staff economist with the Council of Economic Advisors, Washington, D.C.
Bai Yung Sung, Ph.D. University of Minnesota, is an assistant professor in the Department of Economics, Sogang University, Seoul, Korea.
Alberto Veiga, Ph.D. Purdue University, is an economic advisor to the Minister, Ministerio da Agricultura, Brasilia, Brazil.
Ernesto C. Venegas, Ph.D. University of Minnesota, is a forecast analyst for the State of Minnesota Energy Agency, St. Paul.

OBITUARIES

David A. Clarke, Jr., professor of agricultural economics at the University of California, Berkeley, died July 31, 1974 after a long illness.

Dr. Clarke was born in Milford, Connecticut on February 26, 1919. He received a B.S. and M.S. in agricultural economics from the University of Connecticut in 1940 and 1942, respectively, and the Ph.D. degree in this field from the University of California, Berkeley, in 1951. As a lieutenant in the U.S. Army, Quartermaster Corps, he served at several stations in this country and the Philippines during World War II. His various appointments at the University of California, Berkeley, ranged from research assistant to professor, chairman of the Department of Agricultural Economics, and director of the Giannini Foundation of Agricultural Economics. During leave from the University, Clarke held a postdoctoral appointment with the Cowles Commission and served as officer-in-charge of the New Haven Field Office of the Agricultural Marketing Service. He was widely sought as a consultant to federal and state agencies, the courts, and producer and marketing firms.

Dr. Clarke's primary professional interest was agricultural marketing; he was especially concerned with the marketing and pricing of milk and with government regulation in this industry. He was the author of numerous research papers and public documents and the recipient of numerous awards and commendations. His published work, while dealing mainly with a single commodity, was broadly oriented with emphasis on costs and efficiency in the production of marketing services, product pricing, market structure and performance, and legal and public policy aspects in a major and closely regulated industry. His work was motivated by respect for analysis and objectivity and a concern for social justice within an enterprise system. These qualities were consistently expressed in all of his research, teaching, and university and public service activities.

Dr. Clarke is survived by his wife, Dorothy, and his children, Marilyn, Sandra, Alan, and Margaret, all residents of California, and by his mother and sister of Milford, Connecticut.

Rex Warfield Cox died on October 29, 1974 in Fargo, North Dakota at the age of 86. He is survived by his wife, Katherine, and a daughter, Dawn Salisbury.

Dr. Cox was born in Cerro Gordo, Illinois on October 12, 1888. He received his B.S. from the University of Illinois in 1914, his M.S. from Cornell University in 1923, and his Ph.D. from Cornell in 1930. He spent a total of sixty-two years in educational work. He taught at the Eighth District Agricultural and Mechanical School in Madison, Georgia from 1910 to 1912. In 1914–15, he taught at Hillside Home School in Spring Green, Wisconsin. He was an instructor at Fort Hays State Normal School in Hays, Kansas in 1915–16 and at Park County High School in Livingston, Montana in 1916–1917. He was a teacher at Pana Township High School in Pana, Illinois in 1917–18 and was on the staff of Eastern Kentucky State Normal School for 1918–22. He was an assistant professor at Eastern Kentucky State Teachers College in Richman, Kentucky from 1923 to 1927. He was brought to the Department of Agricultural Economics at the University of Minnesota in 1929 by Dr. O. B. Jesness and served as assistant and associate professor until 1957 when he retired. He was on the staff of South Dakota State University in Brookings, South Dakota during 1957–59 and served on the Upper Midwest Economic Study Group, University of Minnesota and Minneapolis Federal Reserve Bank from 1959 to 1962. He came to North Dakota State University as a visiting professor in 1962 and retired in 1971.

Dr. Cox was a member of Phi Kappa Phi, Gamma Sigma Delta, American Men of Science, American Marketing Association, and the American Agricultural Economics Association. He was made a Kentucky Colonel in 1968 and was given a Distinguished Colleague Award by the Department of Agricultural and Applied Economics, University of Minnesota in 1974.

He was noted for his interest in students and in their education. He taught agricultural marketing and statistics at four institutions for over forty-two years. His research included grain, poultry and livestock marketing, agricultural prices, and economic feasibility studies, along with the economics of rural development and outdoor recreation.

He was known to all for his friendly, fatherly interest in the welfare and learning of his many students. He was a gracious, sympathetic man who until his last day gave comfort and good will to all who came his way.

INSTITUTIONAL MEMBERS, 1974

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FINANCIAL MANAGEMENT

The Official Journal of the
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Articles

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Volume 69 December 1974 Number 348

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INFORMATION ON SUBMITTING MANUSCRIPTS

1. **Cover letter.** Please state whether you have published or are in the process of publishing the material elsewhere, including the details of such publication.

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3. **Typing.** Double-space all material, including footnotes, tables, quotations, and references, on 8½ by 11-inch standard weight white paper with margins on all sides of at least 1¼ inches.

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11. **Review by colleagues.** Authors are strongly urged to have their manuscripts critically reviewed by their colleagues prior to submission.

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OBJECTIVE

The objective of the association is to further the development of systematic knowledge of agricultural economics for the purpose of improving agriculture and agriculture's contribution to the general economy.

The principal activities of the association include the following:

- publishing the *American Journal of Agricultural Economics;*
- planning and conducting meetings of the membership in August and December;
- sponsoring annual awards for the outstanding article published in the *Journal,* for the three best doctoral theses and the three best masters theses in the field of agricultural economics, for three outstanding reports of research in the field, for distinguished teaching in the field, and for outstanding extension programs;
- stimulating interest in agricultural economics among undergraduate students;
- publishing periodically a biographical directory of the Association's membership;
- recognizing outstanding agricultural economists through an honorary Fellows program.

MEMBERSHIP

Membership in the association is open to persons having a professional interest in agricultural economics. Dues are payable at the beginning of each calendar year. The rates are as follows:

• Regular membership	$15.00
• Junior membership for students (3-year maximum)	$ 5.00

Applications for membership, payment of dues, changes in address, or inquiries regarding the general affairs of the association should be addressed to John C. Redman, Department of Agricultural Economics, University of Kentucky, Lexington, Kentucky 40506. Students applying for junior memberships should use application forms available from and signed by the head of the department in which they are studying.

American Journal of Agricultural Economics

Volume 57 Number 2
May 1975

In this issue: Proceedings papers from the 1974 winter meeting

AMERICAN AGRICULTURAL ECONOMICS ASSOCIATION

American Journal of Agricultural Economics

For volumes 57–59:

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Editorial Policy

The purpose of the *Journal* is to provide a forum for creative and scholarly work in agricultural economics. Thus, acceptable manuscripts should have a relationship to the economics of agriculture, natural resources, or rural and community development. Contributions, methodological or applied, in the business, extension, research, and teaching phases of agricultural economics are equally encouraged.

Editorial Communications

All manuscripts and editorial correspondence, except that concerning "Books Reviewed" and "Books Received," should be addressed to the editor, William G. Tomek, Department of Agricultural Economics, Cornell University, Ithaca, New York 14853.

Communications concerning books for review and books submitted for announcement in the *Journal* should be sent to the book review editor, Francis E. Walker, Department of Agricultural Economics and Rural Sociology, Ohio State University, Columbus, Ohio 43210.

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American Journal of Agricultural Economics

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Proceedings

Articles

Notes

Publications

Books Reviewed

News

Proceedings

Some Avenues for the Improvement of Price Forecasts Generated by Macroeconometric Models

Joel Popkin

Always hazardous, the prediction of price change appears to have become even more so in 1973 and 1974. This is true regardless of the forecasting method used. The purpose of this paper is to suggest ways in which price forecasts generated from econometric models can be improved.

But first it is helpful to get some idea of the extent to which econometric models underpredicted the inflation of 1973–74. The average increase in the GNP deflator projected by eight econometric models in December 1972 for 1973 over 1972 was 3.4%; the actual increase was 5.6% (U.S. Cost of Living Council, p. 171).

For 1974, quarter by quarter predictions of the GNP deflator made in December with four widely used econometric models and the actual change are given in table 1. Again the errors are substantial. When fourth quarter 1974 results are in, the GNP deflator, on a year over year basis, is likely to show a rise of 10% from 1973 to 1974 as compared with a forecast rise of 6.9% implicit in the average quarterly predictions of the four models. Over the 1972–74 period as a whole, these predictions of price change averaged two-thirds of the actual percentage change.

In the specification of the typical econometric model built along Keynesian lines, there are four places to look to as sources of prediction errors: (*a*) prices that are treated as exogenous—usually those for crude industrial and farm commodities and imports, (*b*) wage rates, (*c*) output per man-hour and, (*d*) a variable markup over actual and/or standard unit labor costs and prices assumed to be exogenous (Eckstein, particularly pp. 309–24).

Exogenous Prices

There are two ways in which exogenous prices can influence price forecasts. The first is by virtue of the assumptions made about their future behavior and the second is the way in which they enter the model.

It is clear that assumptions about crude commodity and import prices were substantially off track in 1973 and 1974. The magnitude of the worldwide explosion in primary industrial commodity prices that began in the fall of 1972 and continued, almost without interruption, through the spring of 1974 was largely unanticipated. In the third quarter of 1974, the wholesale price index (WPI) component for crude industrial materials was 74.3% above its level in the second quarter of 1972, just prior to the onset of "commodity" inflation. In 1972, crude industrial material consumption is estimated to have represented 3.6% of U.S. domestic consumption (GNP less exports plus imports in 1967 dollars) (Popkin 1974a, p. 250). From the second quarter of 1972 to the third quarter of 1974 the deflator corresponding to U.S. domestic consumption rose 19.5%. Assuming short lags and dollar for dollar pass-through, the increase in the WPI for crude industrial materials would have accounted for 14% of the rise in the deflator.

The U.S. Department of Agriculture index for farm foods rose 37.5% from 1972-IV to 1974-III. In 1972, farm products accounted for 3.8% of U.S. domestic consumption (Popkin 1974a, p. 250). Again assuming short lags

The papers in the "Proceedings" section were presented at the winter meeting of the American Agricultural Economics Association held in conjunction with the Allied Social Sciences Associations in San Francisco, December 28–30, 1974.

This and the following five papers comprised a session, "Evaluation of Econometric Models for Forecasting within the Agricultural Sector and the Total Economy," chaired by R. A. Schrimper, professor of economics at North Carolina State University.

Joel Popkin is with the National Bureau of Economic Research.

Table 1. Econometric Projections of the GNP Deflator for 1974 as of December 1973

	Quarterly Percentage Changes at Seasonally Adjusted Annual Rates			
	I	II	III	IV
Chase Econometrics	6.7	5.6	6.0	5.9
Fair/Princeton	5.8	4.8	4.1	4.2
DRI	6.2	6.6	6.4	6.1
Wharton	7.1	7.2	7.2	7.2
Average	6.4	6.0	5.9	5.8
Actual	12.3	9.4	11.5	n.a.

Source: U.S. Cost of Living Council, p. 369.

and dollar for dollar pass-through, they accounted for 7% of the 19.5% rise in the deflator for U.S. domestic consumption from 1972-II to 1974-III.

If forecasters assumed no change in crude materials prices, these elements together —crude farm and nonfarm prices—would have accounted for 21% of the rise in the deflator for the U.S. domestic consumption or almost two-thirds of the average prediction error made in the econometric forecasts cited above.[1] This calculation is only meant to be suggestive of the limit of forecast error that could have been made. Obviously forecasters did not assume that crude materials prices would be unchanged, but they did underpredict the rise, particularly for crude industrial materials prices.

Another limitation of the analysis is that there are considerable difficulties in matching price indexes with the quantity weights that apply to the consumption of crude materials. Imported crude oil is not priced for the WPI. There are no prices in the WPI for many items included in the quantity weight for forest products and minerals other than fuels. Supplies of logs, copper ore, and bauxite are largely captive or are sold under long-term contracts. Prices of such commodities appear in WPI components only after they have been partly processed into such things as lumber, copper wirebar, and aluminum ingot. In these forms they represent a larger share of value added. If we broadened our definition of crude commodities to include partly processed materials—the category might be called primary commodities—the contribution of price increases in this larger group would probably be greater than of the more narrowly defined crude commodities.

But whether this would be an appropriate treatment depends on whether the implicit prices of the raw materials from which these partly processed commodities are made actually rose enough to account for all the increase in prices of slightly processed materials or whether increases for the latter reflected shortages of processing capacity as compared with demand. If the second, as is the widely held view for industries such as paper and chemicals, then the effect of these price increases for partly processed industrial materials may be missed for other reasons, covered below, such as the failure to reflect adequately capacity utilization in these industries.

This question aside, it is clear that we need better predictive models of crude materials prices, and that requires improving the specification of the price determination mechanism in these markets. Can we develop such models and at what cost? On these issues I am interested in what the authors of the other two papers in this session have to say. They are addressing only one part of crude commodity markets, but it is probably the most important. Agricultural commodities accounted for slightly more of U.S. domestic consumption in 1972 (3.8% in 1967 dollars) than all other crude commodities combined (3.6%)—forest products, fuels, and other minerals. And they now influence about one-fourth of the consumer price index (CPI) market basket—that for food at and away from home—even more when one takes into account fibers and tobacco products, prices of which enter the nonfood commodity component of the CPI. Better models are needed in the agricultural sector.

Second in importance are mineral fuels—2.4% of U.S. domestic consumption in 1972. Fuel products account directly —gasoline, motor oil, fuel oil, coal, natural gas, and electricity—for 6.3% of the CPI and perhaps half as much again indirectly. Models must be developed for raw fuel prices.

Crude materials other than agricultural commodities and raw fuels have a very small weight in domestic consumption—0.4% for forest products, 1% for minerals excluding fuels, and, as mentioned above, there are no markets for important items in this group. Perhaps the best strategy is to build models of markets for commodities at the partly processed level. There is always the problem of

[1] This assumes the prediction error for the domestic consumption deflator was the same as for the total deflator.

defining the scope of such markets. The Federal Reserve Board has begun recently to measure output and capacity for a selected group of slightly processed commodities it terms major materials ("Capacity Utilization"). The ones they have selected accounted for 8.5% of value added in manufacturing in 1967.

The foregoing suggests that to improve short-term price forecasting we need to know more about the formation of prices of agricultural commodities, fuels, and crude or primary nonfood, nonfuel commodities. And the models need to be worldwide in scope. The next question is, At what level of detail must models be developed? This would appear to depend on the relative importance of supply and demand in the short run. Where demand for particular commodities is clearly more important and is related to aggregate demand, aggregation is possible. This would seem to be the case in the nonfood, nonfuel areas. For agricultural products, supply appears to dominate. Because of the uniqueness of supply-shifting events and their timing, more disaggregation is undoubtedly required. But even if it were not, we would want separate models for farm foods and nonfoods because demand shifts affecting these groups are likely to be different functions of aggregate demand. And for the foods, we would want to distinguish between "final" farm foods and intermediate agricultural inputs such as corn for feeding purposes.

The only rule I can suggest to improve short-term forecasting is to order priorities in terms of the importance of the products in final demand, modified to take account of important cross price elasticities.

The second issue with respect to crude and slightly processed commodities—domestic and imported—is how they should enter macromodels. The usual model contains only an index of domestic farm product prices which usually enters the equation for the deflator for personal consumption expenditures as a cost. Import prices are usually included as an aggregate; crude, semiprocessed, and finished goods and services are combined. Prices of crude domestic nonfood commodities rarely appear. There is no mechanism to capture the effect on prices of domestically produced goods of changes in prices of foreign produced substitutes. This has created a considerable problem in "accounting" for the impact of crude commodity prices on the overall WPI. Import prices need to be disaggregated into the stage-of-process categories listed above, and prices of crude and semiprocessed goods imported from abroad need to be included in price equations for their domestic counterparts.[2]

Another aspect of the way in which raw commodity and import prices should enter macromodels has to do with the specification of the lag structure by which these prices influence prices and other variables in final markets. This requires detailed analysis particularly if the model is to be useful in predicting turning points. The time pattern of the impact of an increase in crude oil prices on the CPI differs among consumer products like gasoline, plastics, or asphalt roofing.

Given the disaggregation of the price-determining mechanism that seems to be required to improve the predictive accuracy of macromodels with respect to inflation, I would argue that a promising avenue of research is to integrate price determination in markets for specific primary commodities into a stage-of-process price model which in turn can be imbedded in a macromodel framework. It is not surprising that I take this view; much of my recent research has been directed at the development of such a model (Popkin 1974b). The stage-of-process sectors involved are shown in figure 1. The advantages of such an approach are: (*a*) it is structured to capture behavior at the most important junctures of the transmission process; (*b*) the use of input prices permits the explanation of gross output prices (these prices, not value added deflators, are determined in markets); (*c*) a model built along these lines can be disaggregated sufficiently to study the impact on final demand prices of price developments in the three major raw commodity markets—those for agricultural products, raw fuels, and raw industrial commodities; (*d*) the model need not be disaggregated to a level at which the data on a monthly or quarterly basis needed to determine the lag structure are not usually available; (*e*) the wage and many of the excess demand variables needed in addition to input prices to explain prices at any stage-of-process are generated by most macromodels, so a linkage potential exists; (*f*) import prices, available by stage-of-process, can be linked in

[2] When this was done in a stage-of-processing framework, prices of internationally traded primary commodities and imported semifinished manufactures were found to account for 31% of the rise in the WPI industrials component in 1973 (Popkin 1974a).

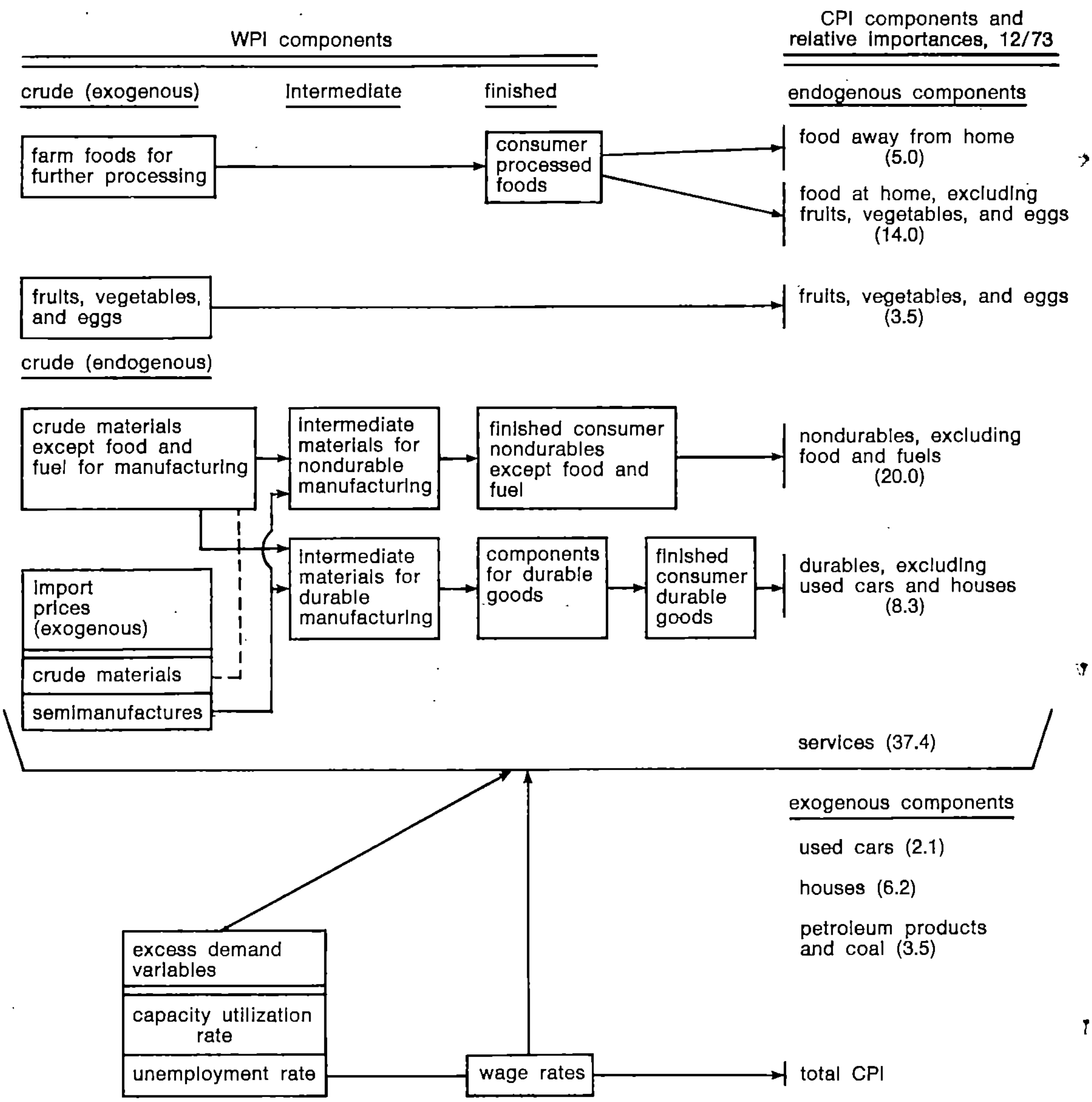

Figure 1. Stage-of-process model framework

at the appropriate places; and (*g*) the lag structure can be determined more precisely, using specific a priori information pertaining to certain sectors.

An alternative approach to stage-of-process is to deal directly with the mechanism stage-of-process as an approximation to an input-output table.[3] This alternative would appear to be of particular importance in long-run models where one is interested in studying the impact of various growth paths on developments in specific industries. Here detailed specification is important. (It is still important to use gross output rather than value added prices.) But for short-term forecasting, the objective should be to improve the specification of macromodels enough to obtain predictions of rates of change of aggregate price levels and those of major component prices that are sufficiently accurate to provide a reliable signal of turning points. To achieve this objective it appears that generating better predictions of the behavior of primary materials prices and using a crude transmission mechanism ought to improve the results.

[3] The stage-of-process approach is consistent with a particular I-O matrix, one that is triangular.

Wages

In a period of time when so much of the rise in prices can be traced to increases in primary commodity prices, which were underestimated, there is a great tendency to put aside problems in predicting wages. These problems were particularly acute in 1970–71 and led some to abandon their Phillips curve notions, still others to alter the way in which the unemployment rate variable should be measured. From 1968 to 1971, deferred increases under collective bargaining agreements were smaller than increases received by the nonunion worker. The latter group kept up better with the accelerating pace of inflation from 1967 to 1970. The acceleration of wage increases in 1970–71 reflected developments in the unionized sectors, developments which arose because wage increases for unionized workers had lagged behind those of nonunionized workers.

It would appear useful to develop separate wage equations for unionized and nonunionized workers. There is a new Bureau of Labor Statistics series on effective wage rate changes for private nonfarm workers under collective bargaining agreements. It has three components: first year settlements, deferred increases, and cost-of-living adjustments. An equation explaining contract settlements, together with information on the number of workers covered by cost-of-living adjustments and the average adjustment for each one percentage point rise in the CPI would provide the data needed to project the effective wage rate series. The difference between movements in this series and the adjusted average earnings series for private nonfarm workers could be used to construct a series for nonunion wages in the private nonfarm sector. This series could be explained in a second equation. The two could then be combined to provide a total wage rate projection.

Output per Man-Hour

While one can appear to discuss improvements in the price determination mechanism in macromodels without talking about output itself, such sleight of hand is far more difficult when one talks about output per man-hour. But my purpose here is not to explore the entirety of a typical macromodel, so I will limit my comments to only one. There is much to suggest that the short-run behavior of output per man-hour differs markedly as between the manufacturing and other private nonfarm sectors (see table 2). Since some models now incorporate manufacturing output through use of I-O tables, it would be useful to experiment with the estimation of separate labor demand equations for each sector.

The Markup Variable

The variables most frequently used separately or in some combination to reflect changes in markups over standard and/or actual unit labor costs are the ratios of output to capacity, inventories to sales, and unfilled orders to shipments. The last mentioned variable is available only for the manufacturing sector. The ratio of inventories to sales is rarely sig-

Table 2. Changes in Output per Man-Hour (All Persons) around Cyclical Peaks

	Two-Quarter Changes at Seasonally Adjusted Annual Rates			
Two Quarters Ending	Farm	Private Nonfarm	Manufacturing	Private Nonfarm Excluding Manufacturing[a]
1953:2	21.8	4.4	0.8	6.3
1953:4	13.8	0.5	0.5	0.7
1957:3	−8.3	2.2	2.7	2.1
1958:1	39.8	−1.3	−8.5	2.8
1960:2	0.3	1.1	3.5	−0.1
1960:4	−0.1	0.0	0.2	0.2
1969:4	10.5	−1.1	0.6	−1.9
1970:2	7.7	1.2	2.0	1.2
1973:4	−7.0	−0.4	0.7	−1.0
1974:2	17.7	−3.9	1.6	−6.5

Source: U.S. Department of Labor, Bureau of Labor Statistics.
[a] Derived residually.

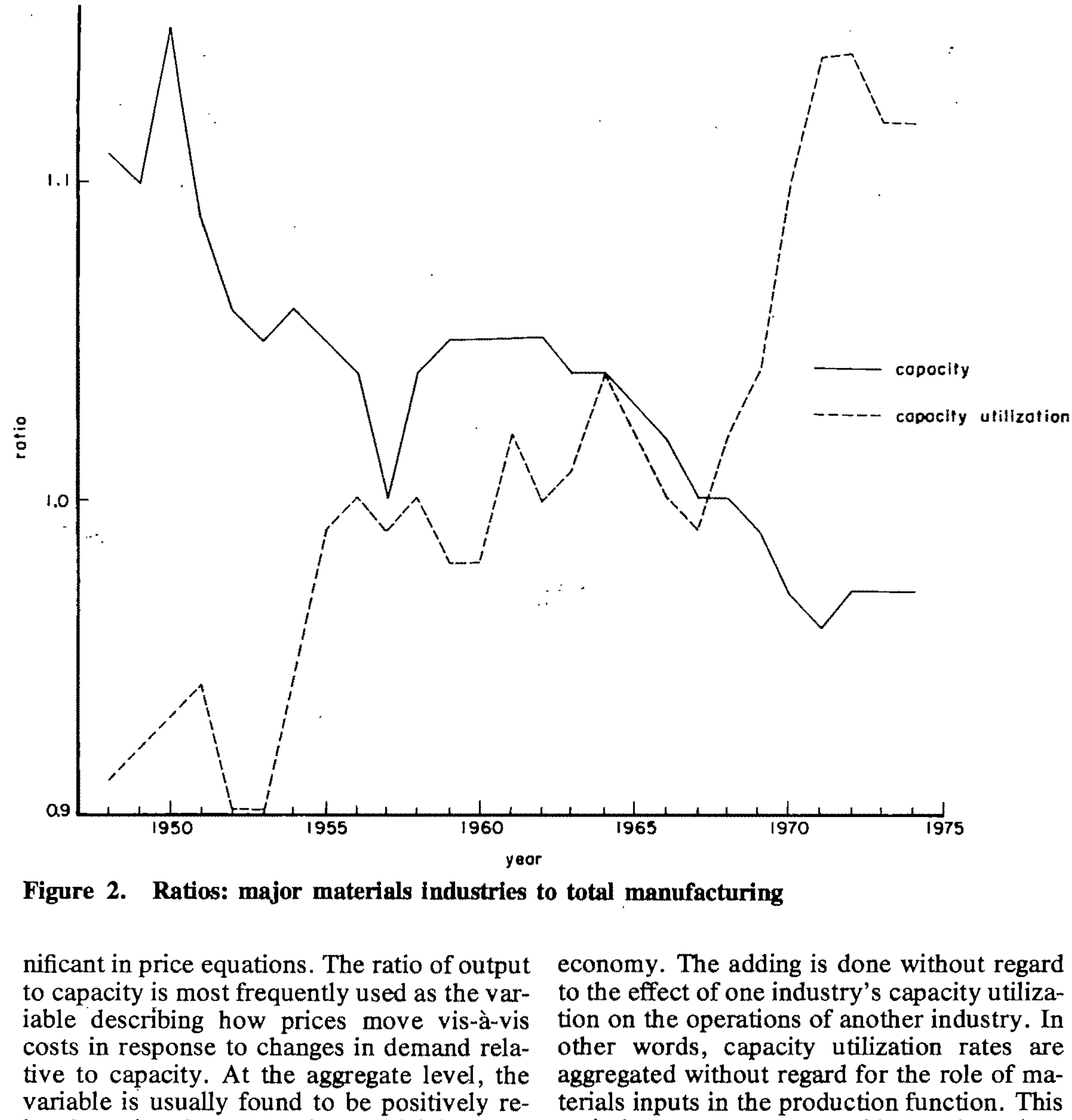

Figure 2. Ratios: major materials industries to total manufacturing

nificant in price equations. The ratio of output to capacity is most frequently used as the variable describing how prices move vis-à-vis costs in response to changes in demand relative to capacity. At the aggregate level, the variable is usually found to be positively related to price change. But in two-digit industry studies the relationship is sometimes negative, implying the increase in capacity utilization occurred to the left of the point of minimum average total or variable cost.

While positively related at the aggregate level to price change, capacity utilization and changes in it usually fall considerably short of explaining the burst in prices that accompanies a rapid increase in economic activity near the zone of full capacity. The basic problem is lack of information about how steeply the supply curve is inclined in this range.

Another problem arises because of the way in which capacity utilization indexes are added to obtain a measure for the aggregate economy. The adding is done without regard to the effect of one industry's capacity utilization on the operations of another industry. In other words, capacity utilization rates are aggregated without regard for the role of materials inputs in the production function. This omission presents a problem when bottlenecks arise.

An indication of the existence of bottlenecks can be seen in figure 2 which shows ratios of both capacity and capacity utilization in major materials industries to those for total manufacturing.[4] Throughout the period 1948–74, capacity in total manufacturing was growing 0.5% per year faster than in major materials. From its trough in 1970 to 1974, output of major materials rose 0.5% per year faster than total manufacturing output. Thus, capacity utilization in major materials industries was

[4] The major materials capacity utilization indexes contained in the total manufacturing series are derived differently from those for the separate major materials series.

squeezed relative to that of purchasers of their output. In addition, the trade balance for major materials changed toward exports during the period. The pressures are obscured when one looks only at the capacity utilization rate for total manufacturing. That ratio peaked at 83.3% in the third quarter of 1973. At the same time, the ratio for major materials peaked at 94.3%. This suggests that capacity utilization measures must be disaggregated to provide an indication of bottleneck pressures.

Conclusions

The improvement of the accuracy of price forecasts in macroeconometric models requires improving the specification of the price determination mechanism. Because of the varied sources of price change, particularly in the relatively short-run forecasting horizon, this requires further disaggregation of the mechanism. But disaggregation is not costless, so it is necessary to consider carefully the avenues through which a minimum of disaggregation can lead to a marked improvement in price forecasting. Several avenues are suggested here: (*a*) submodels need to be developed for major raw commodity markets; (*b*) a stage-of-process mechanism is needed to provide for the transmissions of raw commodity price changes to the aggregate price level; (*c*) wage rate equations should be disaggregated into union and nonunion markets; (*d*) disaggregation of the components of output per man-hour into manufacturing and nonmanufacturing components is likely to improve estimates of unit labor costs; and (*e*) capacity utilization measures need to be disaggregated, probably along stage-of-process lines, to permit the reflection of bottleneck industry effects.

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Econometric Models of the Agricultural Sector

Gordon A. King

The sharp and continued rise in food prices during 1973 and 1974 has directed attention to commodity analysis in particular and to economic forecasting in general. Heller's oft quoted comment that 1973 was a year of infamy in forecasting is hardly the attention one might desire. But if such attention leads to a reevaluation and improvement of econometric models, it will be worthwhile. I prefer to focus attention on such an evaluation rather than explain for one more time that weather can drastically affect production and prices, that a food grain reserve is an important aspect of agricultural food policy, that Russian wheat deals and lack of information can be disruptive to commodity markets, and that a continued search for an improved food and agricultural policy is a must. Dale Hatheway has provided us with an excellent discussion of "Food Prices and Inflation" covering these points. Also, Cromarty will focus on short-term forecasting in the following paper.

The general thrust of this paper is that although agricultural economists have made important advances in supply and demand analysis in the past decade, we have not exposed these models to the same scrutiny on predictive performance as for macromodels of the economy. This may be for several reasons. First, there is considerable publicity given to predictions of GNP by various macromodels; second, the commodity "Outlook" reports of the Economic Research Service generally are not explicit as to the underlying model used; third, with some exceptions, the commodity models published by state experiment station researchers are not designed for the purpose of a continual update, prediction, and evaluation; and fourth, the export demand equations of commodity models are particularly difficult to quantify. Ongoing work in the Economic Research Service in long-term forecasting, trade, and commodity models perhaps will rectify some of these limitations, but it is my impression that a coordinated evaluation of the models is overdue. The symposium on econometric model performance reported in the 1974 *International Economic Review* certainly has no counterpart in the agricultural commodity model building fraternity. This should be done. Further, I suggest that we should move to develop the required data banks, the econometric models, the estimations and simulations of alternative outcomes on a continuing basis rather than what appears to be the present start-stop characteristic of much of our work.

Obviously, econometric models must be used with caution. As Fair points out for the macromodel builders, "The current practice of most model proprietors who issue regular forecasts is to adjust the forecasts from their models before the forecasts are released" (p. 285). Similarly, "Outlook Situation" reports never will be written solely on the basis of printout from the latest econometric model, but it would be useful to examine the basis of these forecasts. With this background, I would like to discuss recent developments in commodity models and then summarize my suggestions for future efforts.

Commodity and Sector Models

Agricultural economists have developed an impressive number of econometric analyses of individual commodities and sector models (such as the feed-livestock economy) during the past twenty years. The late 1950s is taken as a base point for reviewing developments in this field. These developments will be highlighted by example rather than any attempt at a complete survey of the literature.

Demand and price analysis received an important stimulus in the 1950s under the guidance of Fred Waugh, Karl Fox, and Dick

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Foote in the Economic Research Service. Their concept of assigning researchers to work with expert commodity analysts was an important means of attaining a balance between theory and practical insight for econometric analysis. A sampling of studies during this period indicates emphasis on specification of structural models of supply and multiple market outlets on the demand side. Similarly, Nerlove's work on adaptive expectations greatly strengthened the specification of supply models. Although models have tended to include both supply and demand functions, it is apparent that the research often focuses on one aspect, reflecting the author's primary interest, or the problem formulation. Advances in supply response will be discussed first, followed by illustrative approaches to both supply and demand analysis.

Supply Response

Estimation of supply response is of obvious importance for agricultural price and incomes policy, both for short-term forecasting and for long-range projections of land use and resource needs. For crops, acreage and yield projections are required under alternative levels of prices, government programs, input costs, and technology; for livestock, comparable variables are needed. The focus of supply analysis has been on the individual firm, the region, and the nation, with coverage ranging from an individual crop and its major alternatives to land use for crop production in regions and the nation. The approaches vary with the questions raised by the researcher, but these can be classified into three major groupings: (*a*) econometric analysis of time-series data and/or cross-section data, (*b*) estimation of supply response from production function estimation, and (*c*) normative approaches such as mathematical programming. The general position taken here is that the various approaches are complementary rather than competitive, a view expressed previously by Nerlove and Bachman in their excellent review of supply analysis (p. 533). However, in this paper discussion is limited to econometric models.

Important developments include the following: (*a*) refinements of expectations models as to price, yield, and returns; (*b*) explicit treatment of risk in supply response; (*c*) refinement in the incorporation of government policy variables such as effective support prices, acreage restrictions, diversion payments, and farmer participation rates that characterized the period for important field crops; (*d*) analyses of perennial crops using expectations models that include consideration of removals as well as planted acreage; (*e*) more refined models of the livestock sector with consideration of cyclical behavior and the treatment of inventories; and (*f*) methodological advances in estimation procedures, consideration of Bayesian approaches, attention to the updating problem in econometric analysis.

Expectations and Risk

Perhaps the most important thrust has been in research at the micro- and aggregate level on behavioral models relating to producer formulation of expectations of price and yield, and risk. Confining the discussion to econometric models of time-series data, Nerlove's dynamic supply response model is the base point for refinements of the naive assumption that farmers respond simply to last year's price. The question becomes that of specifying this formulation of expectations given asset fixity, uncertainty as to price and yields of various crops, and the like. The models discussed in the literature include extrapolative, adaptive, and rational hypotheses associated with Goodwin, Cagan, Koyck and Nerlove, and Muth, respectively. Due to the unobservable expectations variable, reduced forms of the dynamic models include various distributed lag equations, with the geometric lag perhaps the most common, but with competitors the Pascal and polynomial lags depending on the researcher's view of the relative importance of past values on expectations. A comparison of geometric and polynomial lag models for milk response is given by Chen, Courtney, and Schmitz. An excellent survey of distributed lags given by Griliches clarifies the conceptual differences between the adaptive expectations model and the partial adjustment model which have similar estimating equations as follows: "The adaptive expectations model attributes the lags to uncertainty and the discounting of current information. The partial adjustment model attributes the same lags to technological and psychological inertia and to the rising cost of rapid change. Circumstances (or experiments) are conceivable in which one could discriminate between these two hypotheses.

For example, a government guaranteed price for next year's crop should dispose of most of the information uncertainty. If lags still persist, they must be due to other slow adjustment reasons" (p. 42). I am not aware of any such experiments, but it is an idea worth exploring.

The adaptive expectations model has been widely used in agricultural supply analysis. Estimation of the reduced form by ordinary least squares (OLS) leads to inconsistent estimates due to the correlation of the error term with the lagged endogenous variable, and maximum likelihood methods are suggested. There are arguments for predictive ability versus structural coefficients, however. An important contribution is Behrman's analysis of supply response in Thailand in which desired acreage is expressed as a function of both expected yield and prices plus other variables. Behrman notes the desirability of use of expected net revenue rather than the gross revenue implied by price and yield, but lack of input prices and quantity data prohibited that approach—a comment not uncommon in supply analysis and perhaps indicative of the need for side analyses that would make such information available over time (p. 157). Behrman uses a nonlinear estimating procedure in obtaining structural estimates of the model.

A further advance in this framework is the introduction of risk into aggregate supply analysis by Just. Whereas Behrman treats expected prices and expected yields in his model, Just includes not only producers' subjective evaluation of mean values of gross returns but the variance of such terms for various crops. The introduction of the variance or risk terms is of considerable importance in explaining acreage response in six regions of California, and the implications appear of importance for further work in supply analysis. Just's conclusions are as follows: "Some preliminary results have indicated in cases where risk is apparently important that (1) good fit is often obtained with the reduced form of the standard Nerlovian model, (2) fit usually deteriorates when the structural form of the Nerlovian model is estimated, and (3) fit once again improves when risk variables are added to the structural form. These results then cast doubt or at least should lead us to exercise caution in interpreting and using the large number of studies which make use of the standard Nerlovian model in an adaptive expectations context" (1974a, p. 95).

Government Policy Variables

The incorporation of government policy variables (such as support prices or "effective" support prices, acreage restrictions, diversion payments, and farmer participation rates) into supply analysis has been particularly well done in a series of reports on feed grains and soybeans at Minnesota in cooperation with the U.S. Department of Agriculture. These reports clearly indicate the need for continual updating of analyses as policy changes are introduced or response parameters change over time. In the basic article, Houck and Subotnik formulate regional acreage response functions for soybeans incorporating "effective support prices" for soybeans and competing crops of corn, oats, wheat, and cotton. Briefly, their concept of effective support price incorporates in a single quantitative measure the government support price and acreage limitations. Continuing on this line, Houck and Ryan analyze the impact of changing governmental programs for corn utilizing two separate policy variables. The first is essentially that noted above or a weighted support price based on the announced support price for voluntary or mandatory programs and an adjustment factor for acreage restrictions; the second is a policy variable relating to acreage diversion payments introduced in 1966.

The determination of price and net profit expectations under inflationary conditions of input and output prices is the current challenge. The 1973 farm legislation requires "cost of production" estimates in setting target prices. This challenge to production economists may provide a data base for future work on meaningful "net returns" data for regional and aggregate supply functions. (Of course, improved forecasts of weather and yield would be of no small assistance in short-term forecasts.) This type of research emphasizes the need for complementary approaches to supply analysis.

Perennial Crops

In some regions, perennial crops are of considerable importance and provide challenges for analysis where long-term investments are required. French and Matthews provide a clear review of contributions in this area as well as the specification of a model in terms of

profit expectations for new plantings, acres removed, yield relationships, and supply response. A three-region model provides encouraging results although here again the cost side and thus net revenue expectations cannot be fully quantified. The problem of supply response in tree fruit, for example, is complicated by the yield response of trees over time which in the aggregate is a function of the age distribution of trees. Imposed on this is the general problem of variability of yield by variety, location, weather, and introduction of new varieties and harvest technology. Data simply are not available on important variables, and time-series analyses are thus approximations to the fine detail of a dynamic industry. Government marketing agreements and marketing orders also influence many of these crops and must be incorporated in more realistic supply and demand models.

The Livestock Sector

Analysis of the livestock sector has ranged from the complete supply-demand analysis of Hildreth and Jarrett to innumerable studies of the separate components of beef, pork, lamb, broilers, turkeys, milk, and eggs. There would appear to be a need for an "additive" approach to the individual sector research such that implications might be apparent for the entire feed-livestock economy. However, there has been need for the exploration of new approaches with the fine detail characteristic of the more narrowly defined study. Some of these models specify simultaneous determination of supply and demand relationships, particularly those of quarterly or monthly observations. As with perennial crops, most livestock supply involves some aspect of investment or inventory adjustment mechanism. The length of lag in production response is a function of the characteristics of the industry which may change over time due to market structure and production technology changes, as in the case of broilers.

A good discussion of the inventory model for beef production is given by Reutlinger with a specification of desired inventory and expected input and output prices. An alternative treatment by Langemeier and Thompson gives more detailed treatment to the demand and supply aspects of fed and nonfed beef and imports in a simultaneous equation model. Foote, Craven, and Williams provide an interesting inventory-price-consumption model with explicit treatment of expectations in the Nerlove tradition plus simultaneous treatment of relationships. Freebairn develops a potentially important model of the livestock sector which includes the following aspects: (*a*) an econometric model at the consumer level for fed, nonfed beef, pork, and poultry meat, and margin equations to obtain farm level prices; (*b*) explicit treatment of imports; (*c*) producer decision models for cattle, hogs, and poultry in an expectations framework that includes covariance measures of prices in a risk context; (*d*) an adaptive control framework for considering trade-offs between meat imports and producer prices. This latter point is discussed more fully in Rausser and Freebairn as an approach to policy problems and is deserving of further attention by the profession. Such Bayesian approaches should be explored as to potential usefulness for policy analysis and also for "information updating functions" that are of particular concern to econometric analysis at the present time.

Other important lines of attack concern the nature of livestock and poultry cycles in production and prices. Indicative of the approaches are the following studies. Spectral analysis has potential usefulness in two areas. The first is illustrated in the analysis of broiler cycles by Rausser and Cargill in which they cast doubt on cycles other than seasonal variations in production; the second is in analyses of simulation studies in the validation of results (Fishman). I am unaware of an application to agricultural problems using this approach. A simulation approach in the livestock sector is given by Crom in which alternative policy decisions are traced through. His model includes an extensive number of "operating rules" which are used to modify empirically derived relationships such as, if a certain condition holds, raise a certain estimate by 50%. Such procedures must be used with caution, and certainly the approach would not meet the usual econometric tests.

Demand Analysis

During the past twenty years, improvements have been made in commodity model specification, estimation, and application, including prediction, exploration of dynamic stability, and simulation and cyclical analysis.

Some illustrative examples will be presented. With some exceptions, however, the continual updating and reestimation of relationships is not in evidence in the literature nor is the needed evaluation of predictive power of alternative models. This may be due to several reasons, including the reward structure of the academic side of the profession.

One of the more elegant treatments of a dynamic model is that by Zusman in his analysis of the potato market in California in which consideration is given to market stability, short- and long-run multipliers, and to explicit evaluation of economic policies available to producers. An analysis of wheat by Mo utilizes this approach, building on the earlier work by Meinken. A more current analysis by Barr gives particular emphasis to the effect on price of low levels of stocks. However, treatment of export demand along the lines of Rojko, Urban, and Naive may provide a more viable approach even for short-term models.

In my opinion, the type of commodity model that should be on-line for continual use and updating is the study of soybeans developed over a number of years by Houck, Ryan, and Subotnik. The demand aspects of this model include interrelationships of soybean oil in the fats and oils sector, soybean meal in the high-protein feeds sector, demand for stocks, and world regional demand for oil, meal, and for soybeans as such. An important reason for emphasizing this model is the emphasis given to policy analysis in addition to the high quality of model specification and estimation. It would be useful to the profession if a report could be given on the predictive accuracy of the model over time and the nature of the changes required in specification of relationships due to policy changes, devaluation, and inflation.

Any number of competent analyses of subsectors of the agricultural sector could be mentioned. Models have been improved in specification and new methods of estimation have been used. Seasonal and cyclical analyses have been reported, and, as with supply models, more emphasis has been given to dynamic models. Adaptive control models, although incorporating an objective function framework, still require a solid econometric model if the result is to be more than window dressing. And it may occur that the key control variable, such as import policy, may require estimation of import (or export) functions that are notoriously difficult to quantify. Considerable attention has been given to simulation models in the recent literature, and although they are of interest, they are generally outside the usual bounds of econometric models. A review of such models is being prepared for the Association Literature Review Committee by S. R. Johnson and G. C. Rausser. Also, attention should be given to Shaffer for the importance of subsector research and to French for a useful classification scheme that clarifies the role of econometric studies in a general systems analysis framework. What comes through to me from these papers and approaches is the need for systematic and additive research on the agricultural sector, and an important aspect of this effort should be on operational and updated econometric models.

Need for an Integrated Approach

Stone's continuing research with others under the project A Programme for Growth (see Stone and Barker; Stone, Barker, and Lecomber) is a prime example of the type of integrated research approach that is needed for the agricultural sector. His use of the linear expenditure system is well known. New approaches to the consumer expenditure aspect of the model are reported in an outstanding review article by Brown and Deaton surveying applied econometric analyses of consumer behavior. Another important aspect is the trade sector which is reported by Stone and Barker which is updated periodically. Considerable commodity detail for agricultural products is included to provide the required interface with the input-output sector which has commodity-industry interrelationships. The model is continually being improved, updated, and used for policy analysis. The fine detail needed for agricultural policy analysis is not available in this model.

Although not integrated into the full model, McFarquhar, Mitter, and Evans have developed an agricultural sector model that deserves attention. Essentially the demand sector is based on the linear expenditure system; an agricultural sector input-output model is specified; commodity models are developed for use in projecting supply (acreage and yield); and trade balances are explored. If such a model could be incorporated into the larger model, more attention could be given to the impact of devaluation and inflation, for

example, and to the more macroaspects of the economy. I would like to see the development of such a model for the U.S. agricultural sector but with more explicit recognition of processing sector.

Brandow's base-point study provides much of the needed framework. Developments since that time include the work on separability, with applications to agricultural commodities, inspired by the teaching of George Kuznets (see Bieri and de Janvry). Building on these lines, the study by George and King, I believe, gives one of the blocks needed for an integrated system. The data base is provided in the basic report by Hiemstra which is updated annually. Comparison of alternative models, such as outlined in the Brown and Deaton study, plus the annual update capacity of a modern computer data bank, estimation models, and simulation programs would be an impressive contribution to analysis of the food sector. Research on marketing margin would be another block in the system.

Development of the trade sector is of prime consideration in short-term work, and in long-range forecasting it is of importance to the development of agricultural policy and regional resource development. I think research must proceed along several lines. First, the long-run forecasting of probable export levels reflected in the wheat study by Rojko, Urban, and Naive is essential and probably must be continually revised in the light of energy price changes, population, and income developments in importing countries. Second, detailed analyses of the effect on trade of changes in regional trade groups must be explored, as is so well done in the study by Ferris et al. Third, the regional demand for specific commodities in the short run must be continually evaluated, as would be possible in the Houck, Ryan, and Subotnik soybean study. Fourth, some means must be devised for bringing the trade data together for the diverse groups to provide an aggregate view for regions and the United States as it affects the trade balance. Here, perhaps the approach of Barker (Stone and Barker) will be useful.

Viewed in the light of a comprehensive model, the commodity analysis of supply and demand relationships take on added importance. There is need for research on some of the minor commodities. For example, regional analysis of water development project feasibility generally requires a tie-in with national projections. Yet many of these national projections do not provide the required detail on the important fruit and vegetable crops that may determine the economic feasibility of the project. It would seem feasible with present computer facilities to have side analyses developed that would be consistent with an overall framework of a national model.

General Appraisal

Although considerable improvement is evident in model specification and estimation of models of the agricultural sector, there are several areas to which the profession should give increased attention.

First, as to the predictive power of the models, there is a need for an evaluation of model performance over the past few years. Blakley has pointed out that estimates of demand for food in 1973 in real terms appears consistent with accepted coefficients but that problems may exist with analyses in actual terms due to inflation. This problem faces all forecasters and no easy answer can be offered.

Second, a cooperative effort between the Economic Research Service and experiment station research staffs should be encouraged to develop the capability for rapid update and evaluation of commodity models and integrated demand systems. Too often our inventory of results are outdated and are not on-line for use in policy analysis both at the regional and national level.

Third, more attention should be given to the development of additive research in commodity and sector models and to the development of a broader framework for models of consumer demand, marketing margins, the processing sector, farm supply, and integration of these results into macromodels of the economy of the input-output variety. The trade sector becomes of prime importance in any such modeling. Similarly, the impact of changing input prices, such as energy, becomes more evident in such a framework.

Fourth, continued work is needed on means of incorporating the effects of policy changes, input costs, and technological developments on the supply side, and new products and changing tastes on the demand side. The need for better data, especially as market structures affect availability of published series, is an obvious need.

In conclusion, it is evident that although the

econometrician faces severe tests in such times as these, the nonquantitative economist is apt to be in worse shape!

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Needed Improvements in Application of Models for Agriculture Commodity Price Forecasting

William A. Cromarty and Walter M. Myers

Beginning with the infamous Soviet-American grain deal in mid-1972, unprecedented agricultural price increases of 200% to 400% have precipitated an intense reaction by both government officials and corporate management. The impact of high food prices on the consumer price index was so severe that the administration, for the first time in a postwar history, was compelled to introduce price controls as an economic restraint. With the avenue for cost-plus pricing now blocked, major food processors, manufacturers, and retailers were forced to consider alternative market mechanisms for price protection or face severely reduced profit margins and perhaps even bankruptcy. This created an urgent and demanding interest in agricultural forecast models and techniques as a start in identifying major price moves in high impact commodities.

The purpose of this discussion is to evaluate the usefulness of those commodity models available during the past thirty months and identify areas for improvement. As economists have yet to develop a single good criterion for evaluating commodity price models, we are not qualified to evaluate models of others. The usefulness of research depends not only on the results generated but also on the researcher's ability to evaluate and objectively incorporate extraneous forces over time. Only those in a position to both develop and accept responsibility for a model's results understand its strength and weakness, its failures over time, and the likelihood that these failures will be repeated.

For this reason the specific concentration will be on evaluating those commodity models developed and applied by Connell Rice and Sugar Company and only generally discussing those prepared by other industrial and governmental economists. Clients of Connell and Company, major food manufacturers and retailers, rely on the forecasting work of Connell's researchers when making their purchasing decisions.

Design Analysis to Solve Specific Management Problems

Over the years a tremendous amount of research has been directed toward developing highly complex, multidimensional supply-demand models for exploring past price movements and forecasting the future. Although it is extremely difficult to apply these models to forecasting when the structure is "varying normally" and the extraneous shocks are at a minimum, it is almost impossible to apply econometric models to the experiences from mid-1972 to date when the values taken on by explanatory variables were substantially different from the normal mean values and shocks were commonplace.

Supply and demand models that did prove valuable were those set up to solve specific management and political problems: Will farmers switch from soybeans to corn or vice versa? What degree of price rationing will be required in the summer to guarantee a minimum old crop carryout? How low will corn prices fall during harvest? Following the harvest low, will price appreciation justify inventory accumulation? What will be the direct impact of food prices on the consumer price index, on wage settlement, and on the balance-of-trade payments?

These were the various types of problems faced daily by each producer, handler, processor, or merchandiser of agricultural commodities and by government officials; they are problems that cannot be solved by research

This paper was presented in a session entitled "Evaluation of Econometric Models for Forecasting within the Agricultural Sector and the Total Economy."

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techniques that are primarily aimed at expressing the power of mathematics and distribution theory in estimating historical patterns and elasticities. In fact, there is considerably less interest in average annual price forecasts than many researchers imagine.

Our experience in commodity consulting has shown that econometric models can assist in decision making only if the problem can be directly specified. By focusing on specific decisions of importance, research becomes problem directed and less technique oriented. When the research is completed, it can be immediately applied to problem solutions. For instance, most large corn millers and corn feeders begin accumulating their new crop requirements during the fall harvest period. This they would like to price whenever cash or futures have reached their lowest possible level. In this situation, knowing the average price for corn during the October–December period is not of major importance. What is important is developing an econometric model that by late September will forecast the lowest daily close of the December corn option between October 1 and December 15. We have found that this can be done with a surprising degree of accuracy by using a combination of (*a*) the September 1 crop production estimate, (*b*) livestock prices, (*c*) the number of animal units, and (*d*) corn prices on September 1 in a simple regression model. In the past two harvest periods, we have had to include new crop export bookings as an additional explanatory factor. From 1960 through 1974 the maximum absolute error of this model has been 9¢ per bushel.

Problem Areas in Agriculture Data

After analyzing the U.S. Department of Agriculture's data over the years on domestic crop production, storage stocks, market conditions, and livestock and poultry numbers, our overall conclusion is that the Department does an adequate and acceptable job. Although specific areas of improvement could and have been cited, the lack of satisfactory data has not greatly handicapped most research efforts.

Recently, however, it has been evident that the unavailability of good data on world crop conditions prevented advance identification of market potential in countries which materially affected the demand for U.S. grain. Also, the lack of detailed quarter by quarter analysis of feed fed per animal unit has inhibited the formulation of acceptable estimates of domestic feed requirements.

No other single factor has had a greater impact on U.S. commodity prices than the world supply and demand for food and feed grains: (*a*) the United States is the primary residual supplier of feed grains with 60%–70% of the total and a major supplier of wheat with 30%–40% of the total; (*b*) facing inadequate domestic supplies, countries are importing feed grains rather than liquidating livestock herds; and (*c*) recent government policy is now leaning heavily on agricultural exports to help correct the deteriorating U.S. trade-payments balance.

With such heavy reliance placed on subsidizing exports and export authorizations, it is extremely difficult for an agency outside the government to forecast exports. The trade also treats with caution the U.S. Department of Agriculture's own estimates on potential shipments. What is needed for good commodity price analysis is reliable data on a country by country basis of major crops and livestock production, stocks, consumption, and potential imports and exports on a continuous basis. In addition, published crop reports of foreign governments should be monitored and exporters and importers sampled for their opinion as well as shipping firms and trade organizations. This information should be updated daily if necessary and could be made available in a "current best intelligence report." In this way, individual researchers could formulate opinions as to likely world trade patterns and assign probabilities to the impact of differing trade levels on prices.

Although the government does provide indexes on a crop year basis that relate livestock and poultry numbers to feed consumption, they have yet to develop a system for computing these indexes on a quarter by quarter basis. Without short-term information on animal units, there is no good way to use the quarterly data on stocks and exports in interpreting domestic feed rates. This information would be even more valuable now that we are observing major within-the-year adjustments by principal livestock and poultry groups. It has not been uncommon for cattle feeders to cut placements 30% to 40% in any quarter and for broiler producers to adjust production by 10% to 20% over a twelve-week period.

Although our resource base is limited, our

research shows that the number of animal units on farms during the fall harvest period is one of three important factors in establishing the level of livestock feeding during the following winter and spring period. This demand model will explain approximately 97% of the variation in total corn fed to livestock and has proven valuable in forecasting grain requirements by quarter early in the crop period.

Model Selection and Estimation

A paper presented by Richard Crowder of Wilson and Company at the American Agricultural Economics Association's summer meetings in 1972 identified two groups of model building, the theoretical group and the user group (p. 779). Although both are important, they differ sharply in their approach to formulating and applying econometric models, one group acknowledging rigor and complexity in solving theoretical issues and the other lauding simplicity and judgment in solution to practical questions.

A fundamental and deep-rooted problem arises whenever an attempt is made to bridge the gap between academic excellence and practical decision making. To apply Jacob Marschak's observation that "knowledge is useful if it helps to make the best decisions" (p. 1) is to personally attack most professional economists whose loyalty to a model begins with a Ph.D. dissertation and builds as the economist is recycled back into academia or joins a public research group. After struggling to understand the statistical distribution and sampling properties of an estimating technique and developing skill in handling the numerous programming requirements, it is all too easy for a researcher to become addicted to a specialized estimating technique. If the results cannot then be applied in any appreciable way to decision making, the common rationalization is user incompetence or ignorance.

Nevertheless, by using Marschak's definition of "usefulness" and the experiences from mid-1972 to date, we are in a position to briefly evaluate some of the major econometric estimating techniques and suggest areas for improvement.

Simultaneous Equation Systems

No other econometric technique has attracted more attention and perhaps more resources over the years than simultaneous equation systems. Undoubtedly, because of the strict identification requirements for specifying a system of simultaneous equations, there is no better technique for gaining an understanding of the interdependence of market forces. However, it has been our experience that for short-term decision making simultaneous equations are only of limited value. The greatest single difficulty we have had with simultaneous equations is specifying a structure that adequately describes the area being studied. This adequacy must involve building in mechanisms to account for structural change and yet remaining within the bounds set by data availability. The past thirty months demonstrates all too clearly that it may be impossible to build in satisfactory structure. Second, because of simultaneity, all of the equations must be chronologically consistent and conform to a single decision frame. In most cases we have found an endogenous behavioral variable could best be determined by a subsystem rather than simultaneously within the system. Also, as previously mentioned, decision makers are interested in specific pieces of information in particular time periods and not in a matrix of future price estimates. Third, in many instances an explanatory variable is specified as endogenous in estimation but cannot realistically be forecast ahead with acceptable accuracy. A corresponding problem arises between calling a factor exogenous in estimation and actually determining its exogeneity when forecasts are made.

Distributed Lag Models

Using distributed lag techniques to capture either the dynamic time dependency within a market environment or as a statistical procedure for correcting interdependent disturbances does have a great deal of practical appeal. After attempting to apply lag models over a period of time, we conclude that because of the high degree of autocorrelation characterizing agricultural price series, the contribution of the lagged dependent price variable will generally overpower any additional explanatory factors. This leads to internal estimating statistics that always appear impressive (high R^2 and low standard error) and a final estimate which tends to overshoot or undershoot the major turning points because of the way in which successive forecasts are built up recursively.

The latter problem is extremely critical and

stems not from the form of the distribution function used but from the fact that the lagged dependent variable cannot legitimately be treated as predetermined in forecasting. In the decision making process, missing turning points always results in an incorrect decision.

Unobserved Components Techniques

Straightforward algebraic and trigonometric models that directly depend on the extent and repeatability of underlying time patterns can, if the patterns are significant and consistent, produce reasonably good forecasts. After a graph or power spectrum identifies a regular cyclical or seasonal component, forecasting models can easily be prepared that will relate the series to past functions of time. For example, we have been unable to develop a satisfactory behavioral model for forecasting the average weight at which cattle are slaughtered. However, due to the somewhat regular, recurring seasonal variation, a good predictor was formed by using a series of sinusoids in a single regression equation.

The major complaint with unobserved component models is that they are unable to handle shocks or structural changes that cause sharp, short-term adjustments or alter historical patterns. By using these components to supplement behavioral variables we have found that a portion of this complaint can be eliminated. For instance, a model for forecasting barrow and gilt slaughter can be greatly improved by using a short-term seasonal factor along with the inventory of market hogs, feeder pig prices, and the number of slaughter days.

Summary

It has been our experience that satisfactory structure cannot be built in and models which help management are not presented in the framework of a two-stage least-squares solution or a geometric distributed lag model containing two lag parameters and a first order autoregressive error scheme. They are a composite of techniques plus subjective judgment and intuition on the part of the researcher.

Despite strong personal attachments to particular estmating techniques, there is much to be gained from keeping models simple and working with partial systems of equations. Models that are useful are those which are designed to allow for subjective judgment and which provide a mechanism for incorporating such factors as major policy changes, currency alignment, shifts in world demand, or weather. Also, good forecasting models are designed to incorporate new information as it becomes available. This gives rise to Bayesian or conditional price forecasts. For instance, a forecast of the low for the December corn future option between September 1 and December 15 can be made after the Department of Agriculture releases the July 1 crop production estimate. A new "forecast low" can then be made when the August 1 crop report is released.

The work that Connell and Company had done on egg product prices provides a good practical example of working with partial equations to forecast prices in an appropriate time period. Our research for egg products has been concentrated on forecasting price levels during the spring pack period. In this case the dependent variables have been the May prices for shell eggs, frozen whole eggs, dried yolk, and dried albumen. By design these prices are forecast in January. The price forecasts are for a period when product prices are normally near their low for the year and forward purchasing can be undertaken. The forecast is made after the layer numbers are known for January 1. The model is recursive in the sense that a forecast is made of shell egg prices for May. This in turn is used to forecast prices of frozen whole eggs and this in turn used to forecast prices of dried yolk and dried albumen.

A simultaneous equations model would permit one to view at one time all of the separate parts and one was so constructed. However, it does not give forecasts as accurate as do the simple recursive models.

Table 1 gives an example of the usefulness of this sector model. Given the price level in January and the bullishness of commodity markets in general, the May forecasts represented a drastic decline. The actual prices in May closely confirmed our forecasts with the exception of albumen. However, in our January commodity letter, we did note that we believed the forecast for albumen was on the low side and coverage was made at just above the $1.30 level.

Model Results and Policy Decisions

There is an abysmal gap between even good results from econometric models and implementation into the decision-making pro-

Table 1. Prices of Shell Eggs and Selected Egg Products

	(January) Current	May Forecast	May Actual Average
Shell eggs, Chicago, ¢/doz.	74.0	41.5– 44.0	44.5
Frozen whole eggs, ¢/lb.	46.0	33.3– 35.0	33.5
Dried yolk, ¢/lb.	230.0	144.0–150.0	148.0
Dried albumen, ¢/lb.	175.0	115.0–120.0	147.0

Source: Connell Rice & Sugar Co. 1974.

cess. This is a difficult gap to bridge even at the corporate level where administrators are anxious to apply information to save costs, to increase financial equity, or for other economic or financial reasons. It is almost impossible to incorporate such information at the administrative level of government where the results are infinitely more important. The inertia generated by politics, personalities, and a fear of altering the status quo can negate the best research efforts.

The blame for the gap falls most heavily upon those people doing the research for the following reasons. (*a*) Only the developer of a commodity model understands the correctness of specification within the model and, therefore, the impact that extraneous shocks will have on the results. In some cases, one must be willing to admit that shocks can render the results useless and to recognize that straightforward application of the output would most likely result in the wrong decision. (*b*) Only the developer of a commodity model understands the strength or weaknesses of the data. There is an undesirable tendency for people who need help in difficult decisions to almost unquestioningly regard data presented by the researcher as factual. It may be the best available but the model builder has the best grasp of the errors and, therefore, the probability of making decisions based on a weak data base. (*c*) Only the developer of a commodity model understands that part of the model which consistently gives good forecasts and that part where large forecast errors may exist. For instance, during the past two years the models that forecast animal units or feed grains fed or domestic supply are much more reliable that those which forecast price levels. (*d*) Only the developer of a commodity model understands those factors not included in the model which may have an important influence on the decision to be made. By accepting some responsibility for the results and recommendations one learns to study and evaluate those factors which can greatly alter model forecasts. In some cases this evaluation, although purely subjective, may be the most significant contribution to decision making. Thus, it would be an injustice to the usefulness of commodity models to evaluate only the formal results and not the contribution made by developing an ability to interpret nonmodel variables.

The importance of subjective judgment can be demonstrated by a current situation in forecasting slaughter hog prices. Historically, consumers have demonstrated a money illusion and, therefore, expenditures on meat have corresponded to current dollar incomes. By fitting slaughter hog prices as a function of hog slaughter and cattle slaughter, storage stocks and current disposable income, we get

$$(1)\quad P_h = 55.8 - 0.002\,S_h - 0.002\,S_c - 0.024\,SS_h + 0.136\,NY_c,$$
$$R^2 = 0.97,\ \hat{S}e = \$1.33,\ d = 1.5,$$

where P_h = average quarterly price of barrow and gilts, Omaha (\$/cwt.), S_h = commercial hog slaughter (1,000 head), S_c = commercial cattle slaughter (1,000 head), SS_h = cold storage holdings at the beginning of the quarter, and NY_c = disposable personal income (current dollars).

In second quarter 1974, this equation forecast prices to average \$36.1 per hundredweight, whereas the actual price for that quarter was \$27.7 per hundredweight or a 23% error. By replacing current dollar disposable income with disposable income in real terms (NY_r) and using equation (2), this error can be eliminated:

$$(2)\quad P_h = 27.5 - 0.002\,S_h - 0.004\,S_c - 0.002\,SS_h + 0.384\,NY_r,$$
$$R^2 = 0.94,\ \hat{S}e = \$1.84,\ d = 1.3,$$

where NY_r = disposable personal income (1958 dollars). In second quarter 1974, this equation forecast prices to average \$27.3 per hundredweight compared to the actual average of \$27.7.

Table 2. Slaughter Hog Forecasts ($/Cwt.)

Quarter	Equation (1)	Equation (2)	Difference
January–March	$45.0	$31.2	$13.8
April–June	45.7	30.1	15.6
July–September	50.2	32.6	17.6
October–December	54.3	35.6	18.7

As the internal estimating properties of these two equations are not significantly different, a reasonable assumption at this point is that consumers have altered their buying habits.

As shown in table 2, by using the same estimated values for independent variables we get appreciably different forecasts for 1975. Confronted with this situation the researcher must decide to what extent, if any, consumers have adjusted meat expenditures and to what extent any adjustment will persist.

Decisions of this nature cannot be solved by additional econometric analysis nor can the researcher rely upon the decision maker's judgment in selecting which level is more likely.

Conclusion

It is not difficult to cite specific areas of price forecasting such as the unavailability of good market theory or good data where improvements can and have been made over the years. The most difficult area to identify and quite likely impossible to correct is the inability or unwillingness of most researchers to structure models that will assist in identifying which policy should be followed when pricing opportunities arise.

We suspect that the problem begins with the fascination by economists in applying econometrics to empirically verify in some systematic way either the truth or the falsity of a fundamental economic theory. As the validity of an empirical theory cannot be finalized, researchers have concentrated on the degree of difficulty associated with the estimating procedure and how well the model predicted past reality. Since these models are generally designed to estimate time-series data, it is not uncommon to see the researcher dredge government or industry for applicable problems.

It is our belief that if agriculture commodity models are to be improved and become useful in application they must first be designed to deal explicitly with decisions of major price consequences. These problems must be specific with respect to the actual series being forecast, the time interval involved, and the economic consequences of an incorrect decision. Second, emphasis must be placed on understanding the market structure which generated the pricing problem and on specifying a model that will correctly identify the two or three major factors influencing the solution. Models that serve this purpose are not only simpler and easier to understand, but they generally lead to better forecasts and policy prescriptions. In fact, we have found that there is much more to be gained from a thorough understanding of market forces than there is from obtaining unbiased and efficient estimates of structural coefficients.

Third, the researcher, whether in industry or government, must be willing to assume full responsibility for coordinating and implementing the results. This means being familiar with the data sources, the strength and weakness of objective model analysis, and the politics and personalities involved. Also, the researcher must be prepared to make subjective judgments about the probable impact of information not included or accounted for in the model. This is a continuous task; because research is ongoing there is no such thing as completing a livestock or a feed grain model.

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Some Avenues for the Improvement of Price Forecasts Generated by Macroeconometric Models: Discussion

Robert J. Mackay and Warren E. Weber

The purpose of Popkin's paper is to suggest several methods for improving the ability of macroeconometric models to accurately predict price changes. He begins by noting the dismal performance of four well known econometric models in predicting the inflation of 1973–74. As of December 1973, the average forecast of these models for the rate of increase of the GNP deflator was 6.4% in the first quarter of 1974 with a continuous decline over the year to 5.8% in the fourth quarter. The actual rate of increase of the GNP deflator, however, fell from 12.3% in the first quarter to 9.4%, its lowest level during the year, only to increase between the second and third quarters to 11.5%.

Popkin lists four places to look to for price prediction errors of this magnitude in the typical Keynesian macroeconometric model. The first of these is in exogenous prices, a term which he uses to mean the prices of "crude farm and industrial commodities and imports." Popkin suggests that failure to take account of changes in these exogenous prices could account for "almost two-thirds of the average prediction error made in the econometric forecasts cited above." There is no doubt that Popkin is correct on this point. To the extent that the tripling (or more) of crude oil prices which occurred in the second half of 1973 and the reduction in the supply of food caused by the drought of the summer of 1974 were not taken into account in the forecasts of these econometric models, they would have understated the rise in the GNP deflator. Moreover, the underprediction could be substantial.

As Popkin correctly suggests, one way in which econometric models can overcome prediction errors due to exogenous price changes is to endogenize these prices. His particular method would be to further disaggregate the current models into "stage-of-process" sectors. This method is an approximation to an input-output table. The major portion of Popkin's paper is devoted to discussing this avenue for improving price forecasts. We have two suggestions at this point. First, we suggest that careful consideration be given to the additional costs of expanding the size of current econometric models and to determining whether the expected benefits from the improved predictive ability would justify the expected costs. Our second suggestion is that, if it does not already do so, the stage-of-process approach should allow for the potential factor substitution that might occur as a result of relative price changes rather than being the fixed coefficient production type used in input-output analysis.

Popkin spends a great deal less time discussing his other three avenues for improving the accuracy of econometric price forecasts than he does discussing the stage-of-process approach. The first of these suggestions that he mentions is to disaggregate the labor sector into unionized and nonunionized sectors and to develop separate wage equations for each sector. Along these same lines, he suggests that changes in output per man-hour could be better captured, at least over the short run, by separating the manufacturing sector from the other producing sectors. Finally, he suggests that capacity utilization measures be further disaggregated in order to obtain a better indication of the slope of the aggregate supply curve and the amount that price will be marked up over cost.

After our first reading of Popkin's paper, we were tempted to argue that the failure of the econometric models to adequately predict price changes resulted from their Keynesian structure. In short, we suspected that they

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failed to take account of the high rate of growth of the money supply during this period. However, upon checking it did not appear that the rate of growth of the money supply during 1973 and 1974 was that high compared with the overall experience since early 1970. The compound annual rate of growth of the money stock from January 1973 to January 1974 was only 5.4% compared with a 7% average for the previous three and one-half years. (All rates of change cited are from *Monetary Trends*.) And, even though this relatively low rate of growth was achieved by a 10% growth from March through July followed by no growth between July and September, these changes in and of themselves do not appear to be enough to explain the increase in the GNP deflator. Further, we found out that the price predictions of the St. Louis Federal Reserve model for the same period underpredicted the price increases by roughly the same amount as the models cited by Popkin. (The prediction of the St. Louis model was kindly provided to us by Keith M. Carlson.) Therefore, to adequately explain the poor predictive performance of the econometric models for 1974, it may be necessary, as Popkin suggests, to look at the unique circumstances of this period.

An important circumstance that Popkin does not discuss, however, is the dismantling of domestic price controls. Part of the price increases in 1974 may be due to lagged adjustments in prices after the removal of wage and price controls. Given the uniqueness of this experience and the nature of econometric models, it is not surprising if they fail to adequately predict the price response following a dislocation such as the imposition and subsequent removal of controls. Obviously, the list of special circumstances can be greatly lengthened beyond exogenous price increases and the dismantling of price controls. We wish, however, to turn from this particular historical experience and consider a broader and possibly more fundamental question.

Let us make the supposition, which may or may not be true, that econometric models continue to predict poorly in the future. Is the explanation always unique circumstances? Is the solution always in more disaggregation? People, economists and policy makers included, will lose confidence in econometric models that always rely upon special circumstances to explain poor predictability. And disaggregation is not necessarily the answer to prediction problems. First, it is not costless. Second, aggregation may have predictive benefits if the aggregation combines the error terms in the individual equations in such a way that the variance of the error term in the aggregated equation is reduced.

We wish, therefore, to suggest an alternative approach for improving the predictive performance of macroeconometric models. Our suggestion follows from some of the recent work of Robert E. Lucas, Jr. In his paper, "Econometric Policy Evaluation: A Critique," Lucas states: "Given that the structure of an econometric model consists of optimal decision rules of economic agents, and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that any change in policy will systematically alter the structure of econometric models" (p. 33).

It is quite clear from even the most casual empirical observation that the Federal Reserve Board has changed the "rules of the money game." The rate of growth of the money supply was approximately 2% during the fifties, approximately 4% in the early sixties and 6% in the late sixties, and approximately 7% in the seventies. The acceleration in the rate of growth of the money supply has been accompanied by an acceleration in the rate of inflation. Whereas it may have been reasonable for businessmen and consumers to expect a trend rate of inflation of around 2% or less in the fifties, it may now be reasonable for them to expect not only a high rate of inflation of, say, 7% but even a rising rate of inflation.

To the extent that econometric models are based upon behavioral equations which describe the behavior of the fifties and even the first part of the sixties, they may predict poorly in the seventies. It is no longer optimal for decision makers in the seventies to have the same expectations formation equations and, as a result, they may respond differently to price changes now than they did before. Such changes in their behavioral responses will lead econometric models, which have not taken account of such changes, to predict poorly.

As a result, our suggestion for improving the predictive ability of econometric models is not further disaggregation. Rather, it is to first go back and examine the econometric models to see how changes the government has made in the "rules of the game" might have influenced the structural equations in these

models. If it is found that these changes in policy could have caused changes in the behavioral equations, then their effect should be taken into account and the predictions tried once again. If it is still found that the models do not predict well, we would then go along with Popkin's prescription of further disaggregation. In conclusion, we want to point out that the necessity of determining how the "rules of the game" enter into an econometric model and how changes in the rules affect the structural equations hold not only for models of the entire economy, such as those cited in Popkin's paper, but also for models which have as their objective prediction within subsectors of the economy.

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Econometric Models of the Agricultural Sector: Discussion

Luther Tweeten

King cites numerous instances of imaginative econometric contributions by individuals which unfortunately constitute a fragmented, nonadditive research effort. His major contribution is to emphasize properly that econometric analysis has failed to contribute fully to forecasting and decision making in agriculture for lack of a comprehensive, sustained effort.

My discussion relates primarily to (*a*) the institutional makeup of the profession which explains the paradox of meaningful parts forming a meaningless whole and (*b*) the strengths and shortcomings of econometric contributions which he omitted.

The speakers at our annual meetings who protest overemphasis on econometrics in our profession and readers of our *Journal* who are turned off by the sterile compendium of mathematical papers of little use to decision makers should neither be taken too seriously nor ignored. I suggest some institutional and other changes as ways to improve the existing situation.

Institutional Structure

Fragmented econometric contributions simply mirror the fragmented institutions which perform and support such research.

Universities

Universities now possess neither the funds nor the framework to operate for many years the needed comprehensive econometric model of food and agriculture. Research performed by graduate students is expected to be original and devoid of hard, relentless deadlines for results. Research is frequently published and discontinued with attainment of the graduate degree. Professional journals notoriously reward elegance not relevance. In short, universities are performing as expected, producing the "one-shot" contributions heralded by King.

Federal Grant Agencies

Federal grant agencies offer no solution. Such agencies rarely can assure continuing support, if for no other reason than that their funds are uncertain. I note widespread conviction among social scientists that the grants process itself is riddled with nepotism and chicanery, degenerating from the mild pejorative "grantsmanship" to the base pejorative "gamesmanship." Even for institutions with distinguished records of research productivity, the total annual value of resources used to obtain grant funds frequently exceeds the value of grant monies received. Pulver provides an additional critique: "In recent years greater reward has been given skillful grantsmanship than program results. Dollar support has too often been based on whom you know rather than what you could do. More energy has been expended in filling out affirmative action forms than in hiring minorities. If we are to successfully set aside growing public cynicism and replace it with public confidence in the institutions of our society, we must learn to reward results rather than gamesmanship" (p. 40).

U.S. Department of Agriculture

The U.S. Department of Agriculture is a logical institution to perform the development function, building a comprehensive econometric model of the agricultural sector and transforming basic and applied research into a form useful to decision makers. But it too has been plagued by institutional problems inimical to

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the development of a large model with necessary continuity. Until recent years, salaries were often inadequate to attract and hold the best people in "engineering" roles. Able people progressed through the reward system only by becoming administrators. Frequent reorganizations, legislators and others hostile to analytical techniques they did not understand, and arbitrary compartmentalization of personnel into marketing, production, and econometric groups (rather than into task or problem-solving groups) retarded progress. Though less so than the university system, the federal system inadequately rewards individuals who give years to developing models which have no author, win no professional awards, are more fallacious than felicitous in early years, and are more pedestrian than illustriously pedagogic. Instead of asking, Where are the new Fred Waughs, Karl Foxes, and Dick Footes?, we should be asking, Where are the U.S. Department of Agriculture counterparts to NASA and the space engineers who systematically reached a prescribed goal?

Current leadership in the U.S. Department of Agriculture provides some hopeful signs. Daryll Ray of our faculty with the help of U.S. Department of Agriculture funds and personnel has made a most promising beginning of a national agricultural simulation model, a refinement and extension of his earlier work at Oklahoma State (Ray). Dr. Leroy Quance of the National Economic Analysis Division and his staff have also shown incipient ingenuity in integrating disparate systems toward a meaningful national interregional projections system. His approach is to develop separate models with various degrees of aggregation but to coordinate development so that the models form a consistent whole in reaching prescribed objectives.

National Institute

My suggestion is that an independent National Agricultural Sector Analysis Institute be established at or near a university or in Washington, D.C. One or more of several possible foundations might fund or endow the institute. Essential to success would be a core of very able professionals who not only are skilled in econometric techniques but also in the problems, structure, and forecasting needs of the food and agricultural industries. Additional funding could come from federal and private sources, especially agribusiness firms, but care should be taken so that no one agency provides sufficient inputs to bias forecasts to its advantage. Continuous funding must be assured to survive the difficult gestation period.

Econometricians and Their Models

I now turn from the failings of institutional structures to the foibles of econometricians. These magnificent men and their computing machines are characterized by professional boons cited by King but also by professional banes. Some of the problems, including the demise of statistics and overspecialization, are discussed below.

Demise of Statistics

The triumvirate of statistics, economic theory, and mathematics which together comprise the econometrics paradigm early emphasized statistics. Postwar emergence of linear programming, input-output analysis, simulation, and the extensions of a few statistically estimated parameters to form a complete set including cross elasticities (through economic theory, e.g., George and King; Brandow) leave the profession with few statistical parameters with standard errors for use in forecasting. The now widely used stepwise regression procedures "sampling" independent variables from a large number of theoretically admissible hypotheses invalidate conventional statistical tests of significance. The profession is on shaky ground because satisfactory tests of reliability exist for none of the above quantitative models and cannot delineate the probabilities that the models can predict behavior within given ranges. We currently are using hierarchical techniques suggested earlier (Heady and Tweeten, chap. 15) to alleviate some of the statistical problems of estimating a regression equation from a large set of admissible independent variables.

Specialization

Increasing specialization is essential as the ability of the student to accumulate the growing stock of knowledge squarely confronts the limited time and resources available to acquire that knowledge. The professional cost of specialization is parochialism evident in econometricians so burdened with quantita-

tive training they have no time to obtain the knowledge of institutions, problems, and needs of decision makers. Parochialism is also apparent in research citations, which so often are confined largely to work performed at the author's institution. King makes no claim to an exhaustive review, but I shall attempt to show by presenting omitted contributions from just my own work, let alone that of others, that the profession is poorer for his myopia.

Econometricians including George and King contine to assume quantity rather than price as dependent in the demand equation. Yet the case for price dependent in agricultural commodity models dates at least back to Karl Fox. The quantity of farm output is predetermined from the supply function by past prices, weather, and other factors. Price allocates the given quantity among uses. Demand price is unlikely to react quickly to a change in quantity because of the need for the seller to learn (*a*) whether the change in quantity is permanent, (*b*) what the reactions of other sellers are, and (*c*) if the warranted price adjustment covers the cost and time required to change price tags. Consequently, the price flexibility of demand is greater in the long run than the short run, which is comparable to stating that the price elasticity of domestic demand is greater in the short run than the long run. This conclusion, although stated and empirically supported some years ago by me (1967), has been recently "rediscovered" on somewhat different grounds by Subotnik.

In the very long run, sustained high prices are likely to lead to production and consumption of substitutes not evident historically and hence not apparent in time-series data. Econometric analysis does not register this effect in demand equations. Accordingly, the "true" graph relating price elasticity of domestic food demand to length of run is U-shaped in my judgment. However, these considerations do not apply to foreign supply, which also is an important dimension in the U.S. farm output demand function. The net result is an increasing price elasticity of demand for total farm output with respect to prices received by farmers because of the importance of exports in the long run.

Perhaps the most used, single parameter in our profession is the price elasticity of demand for farm output at the farm level. Despite its central importance to farm policy, only one estimate exists of the parameter to my knowledge (Tweeten 1967). That estimate indicates the long-run price elasticity of demand at the farm level is as high as −1. The elasticity, −0.2, in common use is so much a part of conventional wisdom that few people bother to cite their source. When pressed, they usually indicate that the source is one of several extant measures of the price elasticity of domestic demand for food at the farm level. But this estimate fails to account for inventory, domestic fiber, and foreign (export) demand. All of these latter elasticities are larger than those for domestic food, with inventory demand particularly elastic in the short run and export demand particularly elastic in the long run. Unless account is taken of these elements of demand, predicting a change in prices received by farmers from a change in farm output is likely to go much awry. In short, those who use the elasticity of domestic demand for food at the farm level as a measure of the demand elasticity for farm output are seriously misguided and, for example, overestimate the long-term economic benefits to farmers from supply control.

We also have learned some things about the agricultural supply function of benefit to the profession, not the least of which is that where possible the supply elasticity should be estimated from an input demand equation rather than from a commodity supply equation (see Tweeten and Quance 1969, 1971). Burt was disturbed by our use of the input-output ratio to explain output; the traditional practice, of course, is to use time or other dummy variables to measure technology in supply equations. Analysis (Tweeten and Quance 1971) showed rather conclusively, however, that to substitute a time variable for a productivity variable was to substitute massive specification bias for minute statistical bias.

Other substantive findings from supply analysis included development of a new method to segment variables (Wolffram) and ways to combine unit (e.g., acreage) with yield components of supply as well as ways to combine livestock with crops to determine an aggregate supply response to price from components (Tweeten 1970, p. 244).

Based on our analysis, the problems of determining substitution rates among components are so severe that the economic health of the agricultural industry in the intermediate run or long run is much more conveniently, cheaply, and accurately ascertained from working with aggregate supply and demand

shifters and parameters than from building up aggregate data using disaggregated supply and demand functions (Quance and Tweeten; Grunfeld and Griliches). Thus, the plan mentioned earlier of the National Economic Analysis Division (U.S. Department of Agriculture) to use an aggregate model to constrain the results from disaggregated models appears to have merit.

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Needed Improvements in Application of Models for Agriculture Commodity Price Forecasting: Discussion

Hazen F. Gale

The job of economists is to analyze economic relationships which may cover the spectrum from the very long run when everything can be treated as simultaneous to the very short run when everything can be treated as predetermined. Of course these two extremes are uninteresting to practical men because we cannot hope to develop a comprehensive model to cover the long run and no specialized knowledge is required to analyze the very short run. As a result, economists and econometricians have developed a range of partial equilibrium models to handle the many economic problems that need to be solved to facilitate more efficient operations of businesses, industrial sectors, and national economies. The paper by Cromarty and Myers is concerned mainly with the business sector and its need for short-run forecasting information, though he implies that some of these models would be useful to government policy makers. The paper deals primarily with short-run analysis, but it should be emphasized that the long-run models, the basic statistical models, and comprehensive sector models are the foundations on which the short-run forecasting models depend for their power and reliability.

I am particularly sympathetic towards the idea of melding the formal model results with the judgment of the forecaster. This is not a new idea and all serious forecasters practice it. But many of the models developed in the past several years and presented in the journals have paid too little attention to the details of recording the exact data series and transformations necessary to allow users to test and implement the models. One reason for the success of the Minnesota-U.S. Department of Agriculture models by Houck, Ryan, Abel, and others (Houck and Ryan; Houck, Ryan, and Subotnik; Ryan and Abel) is the effort that has gone into their maintenance and operation.

On the other hand, forecasters should not be misled into only thinking that model results should be tempered by judgment; ad hoc and trend forecasters would often do much better if they allowed the models to influence their judgment.

While at the Cost of Living Council, I was struck by the extremely short-term nature of many of the demands of policy makers. Those demands apparently fall in the same general class as demands by business decision makers: (*a*) When will prices turn down?, (*b*) How high will prices go before turning down?, (*c*) At what price does the supply curve become vertical for short and intermediate periods? Many model builders may be surprised to learn of the widespread interest by business and government policy makers in the lowest or highest price for a particular period similar to the case cited by Cromarty and Myers. As a matter of fact, model builders often treat those observations as aberrations and usually work with quarterly or annual averages which eliminate much of the noise and isolate the signal more clearly. Thus, the paper says that the noise which is usually eliminated by many researchers contains some valuable signals for the business community and those who use the commodity markets. These short-term movements are also important to government officials who watch the critical official price indicators and who must deal with political pressures which are frequently associated with short-term movements. The longer-term, basic govern-

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The author's views expressed in this paper do not necessarily coincide with those of the U.S. Department of the Treasury.

ment policies, however, are still based on longer-term considerations.

Data Problems

The data inadequacies stated in the paper cover most of the important gaps, but a word of caution is in order. They have suggested a sampling of opinion in importing and exporting countries, trade organizations, and shipping firms. Karl Fox, in an internal report to the Council of Economic Advisors on the U.S. Department of Agriculture's forecasting procedures, pointed out that the federal government can ill afford to become dependent on external hearsay for its information. Facts should underlie both government and business decision making; opinions and data from unofficial sources should be used only as a temporary last resort measure. Whenever significant data gaps appear, government should provide resources to fill the gap as soon as possible with official data series. The U.S. Department of Agriculture should facilitate access to its current data base by more effective compilation, processing, and dissemination. One improvement which could be implemented within a short period of time is the seasonal adjustment of its major data series. Many times the seasonal pattern is the greatest source of variation and yet the seasonally adjusted data series are not published on a regular basis for many series. Seasonality in the broiler industry is so important that weekly seasonal indexes of broiler placements have been developed by the industry; yet the U.S. Department of Agriculture does not yet publish seasonally adjusted monthly egg hatchings. Similarly, no seasonally adjusted hog slaughter numbers are published despite the vast amount of documentation on seasonality. The seasonally adjusted series frequently would be much better than the crude "changes from a year earlier" that are now used so widely.

Data on net returns to commodity producers are sorely needed along with associated estimates of supply response. Parity prices have long been derided as inadequate measures of performance of the agricultural sector; yet there is still very little else to rely on. Livestock product-to-feed price ratios are available, but these are only crude estimates of profitability. I might add that these net return data are in great demand by policy makers who seem particularly adept at understanding that a farmer or other businessman is incurring a profit or a loss.

Model Selection

I strongly suspect that considerable work remains to be done in analyzing short-term price movements prior to World War II. For many years we have had excess supplies of grain and have ventured into the upper reaches of the demand curve on very few occasions. Development of analyses to handle problems of the past three years may benefit significantly from intensive study of earlier periods such as 1918–21, 1933–36, 1946–48, and 1950–54 when demand temporarily placed excessive pressure on supplies. If it turns out that the 1955–70 period was unusually stable and we are returning to greater commodity price fluctuations, we should be prepared to make the adjustment quickly and not fumble in the dark for several years to rediscover fundamental analytical models developed years ago. I don't want to imply that new development is not needed, because I feel we do have much to learn about the evolutionary changes in the complex relationships among cattle ranching, the feed grain sector, and the cattle feeding industry. A symptom of this type of ignorance was the large body of opinion that the U.S. Department of Agriculture's Statistical Reporting Service should revise its cattle inventories in 1973 when cattle slaughter failed to come up to expectations based on the number of cattle on feed.

I think Cromarty and Myers slide over the new international implications too easily. It will take considerable resources to rebuild many agricultural models to incorporate the determinants of foreign demand. In addition, we will need to encourage many foreign governments to collect and disseminate the necessary data to use in these expanded models.

Reduced forms are the easiest models to explain to executives; so many forecasters migrate towards simple least-squares models that will accomplish the task at hand with a minimum of effort and considerable flexibility under the pressure of a heavy workload. In the past, the derivation of the reduced-form coefficients from a simultaneous equation model presented some formidable obstacles; so it was convenient to merely estimate the

reduced forms by ordinary least squares. It is just a short step from that technique to the elimination of nuisance variables or to the addition of some extraneous variables to improve the fit.

Cromarty and Myers rely heavily on the level of variables in evaluating the performance of their models. This may be fine for them, but for many forecasting jobs it is the change in a variable that is important. Needless to say, the R^2 drops sharply as one switches from the measurement of level to the measurement of change.

A phenomenon which has arisen in the past two years and which may cause considerable difficulty in the future is the interrelationship among supplies of various commodities. Much work has been done on demand cross elasticities, but we have been able to ignore many cross effects on the supply side. This has changed. To estimate next year's supply of sugar beets, we now must consider the expected price of corn or potatoes. Also, rice production will depend on prices of cotton and soybeans. This process implies a much larger and more comprehensive model than we are used to in forecasting and policy analysis work. The prospect of developing such a model is not good, so judgment becomes particularly critical. At times like these, aggregate models (Quance and Tweeten; Tweeten and Plaxico; Tweeten and Quance) are extremely useful in estimating aggregate price changes when total agricultural output starts running into a short-run capacity constraint.

Model Results and Decision Making

It is noble of Cromarty and Myers to accept on behalf of researchers the large responsibility for the gap between decision making and results of econometric models. He is correct in itemizing the developers' intimate understanding of the model, data, and performance. The decision maker, however, does have an obligation to put forth some effort and I think most of them do. In fact, most executives and government administrators demonstrate unusual charity towards forecasters. Otherwise, based on our recent performance, the turnover would be much higher and the demand for forecasters would be greatly reduced.

More evaluation of agricultural forecasts is urgently needed. It is disappointing that the Economic Research Service is only now getting around to measuring its errors in a systematic way.

Finally, I would like to compliment Cromarty and Myers on their contribution in view of the fact that some of their models and results could lead to a sharing of their trade secrets, to innovations on their methods, and eventually to an erosion of their share of the market. The paper provides some interesting insights into business forecasting and will hopefully lead to further developments by those outside the business community. Perhaps other private forecasters will now see their way clear to share some of their experiences with the profession.

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Impact of Changing Structure of the Food Industries on Food Supply and Price

Forrest E. Walters

The food sector is considered here as the complete chain of industries producing inputs and commodities which are linked to processing and marketing of food; thus, the food sector includes the farm input, farm producer, and food processing, wholesaling, and retailing industries. The economic structure of the food sector is viewed in the traditional framework as the characteristics of industry organization, including the number and size distribution of firms as related to firm conduct and economic performance. The economic question that surfaces concerns the potential of the food sector, in its current economic structural formation, to contribute to domestic food shortages and price inflation. The purpose of this paper is to discuss (*a*) the economic structure of the food sector as it relates to food supply and price and (*b*) alternative policy remedies.

Critics of the food sector regard retail food prices as the result of the economic structure of the domestic food delivery system as well as the interaction of demand and supply (Zawel, p. 2). They note that periods of food shortages, when demand is more inelastic, are regarded as situations that can just happen in a competitive industry but situations that might be contrived in a more oligopolistic industry. Administered pricing as a policy of concentrated industries is also inferred by congressional groups when it is thought that demand shifts downward and prices either increase or do not change (Joint Economic Committee, p. 1). Further, inflation is linked to administered prices that increase despite falling demand.

In this paper it will be argued that the economic structure, characterized at the farm input, processor, and retail levels as oligopoly-like, could, and indeed probably does, contribute to inflexible supplies of food and inflation of food prices. Further, less than competitive supplies and prices are detrimental to the consumer. However, alternatives that would realign the structure of the food industries into less concentrated businesses would cost the consumer in terms of trade-offs that include some likely efficiencies, expanded services, and product variety gained through large resource concentrations and economies of scale.

In an earlier era the costs of the trade-offs necessary to realign the structure of the food industry into less concentrated businesses were considered far too great for vigorous pursuit. In that period, which existed as late as 1966, there is some evidence that the general public for the most part felt that business (including large-scale business) contributed to their well-being. According to selected polls, the majority felt that "most businessmen are genuinely interested in the well-being of the country" and that "business executives are more capable than other executives" (Harris, pp. 22, 24). However, even then, monopolies were considered a real danger to small companies and the public. Now large scale business per se is called into question and only doubtful credibility is given to business ability. Consequently, under such circumstances, the consumer may be willing to accept the costs of alternative remedies.

It should be noted that all food price increases during the current inflation period cannot be attributed to the oligopoly-like parts of the food sector. A wealth of documentation from the U.S. Department of Agriculture shows that commodity and food shortages

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This and the following four papers comprised a session, "Structural Changes in the Food Industry: Implications for Future Public Policy," chaired by Walter G. Heid of the U.S. Department of Agriculture and Montana State University.

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Many of the concepts in this paper are developed from research carried out by a technical committee under the Regional Research Project W-117, "Structural Changes in Agricultural Industries: Causes and Impacts." The author is especially indebted to the technical committee consisting of A. A. Araji, Richard Johnston, D. Courtney, D. Dahl, Smith Greig, Walter Heid, and H. M. Neghassi, and to others, Paul Huszar, Linley Juers, Phil Knox, Rex Rehnberg, David Seckler, and Mel Skold for their perceptive comments.

exist. Further, what appears to be noncompetitive behavior on the part of food firms can result, at times, from state and federal government regulations of the food sector as well as other industries. Examples of such actions include proportional rail rate increases controlled by the Interstate Commerce Commission, selected backhaul regulations for food carriers, natural gas rates set by the Federal Power Commission, long testing time requirements by the Food and Drug Administration, pollution controls by the Environmental Protection Agency, and tax collections and regulations at different market levels at the federal, state, and local levels. In some cases, selected regulations, such as the requirement by the Packers and Stockyards Division of the U.S. Department of Agriculture that custom feedlots divest their interests in slaughterhouses and vice versa, could result in more concentrated ownership of slaughterhouses and lead to reduced competition. Large firms are the most likely purchasers as custom feedlots sell ownership control.

The following discussion will outline the economic structure of the food sector by levels and to some extent show the complexities of determining alternative policy prescriptions that will result in more optimal production, marketing, and pricing of food and food products.

The Farm Inputs Industry

The farm input industries represent a complex of products such as petroleum products, feeds, animal medicines, fertilizers, seeds, pesticides, herbicides, and machinery. Each product or group of products tends to represent a group of business entities that are industries in and of themselves (Minden, p. 678). However, each product or group of products is related as a total industry through the selected development of synergistic sales as seeds, fertilizer, and pesticides, and because the farm input industries sell to a common purchaser, the farm producer.

In general, total farm inputs used by farmers have expanded slightly as farm numbers have declined and as farm size has increased (Dahl and Mather, p. 5). Purchased farm inputs have risen dramatically since 1940 and farm inputs not purchased have fallen significantly over the same period (U.S. Department of Agriculture). From this it appears that the farm producer is replacing labor with services provided by the farm inputs industry or that there is a transfer of labor input to the farm services industry. As a result, it is questionable that the total reduction in labor inputs required to produce food is as great as is implied by much of the literature that applauds the efficiencies of the farm production system.

The farm inputs industry has a peculiar organization. A major part of the industry is accounted for by six major inputs, petroleum, farm machinery and equipment, fertilizers, chemical pesticides, livestock feeds, and farm credit (U.S. Department of Agriculture).[1] Nearly all segments of the industry are dominated by five to ten large companies that have held relatively constant areas of the market since the early 1950s. In each segment, though, the large-scale companies are decentralizing manufacturing operations and moving closer to raw material sources. But as decentralization takes place, firms in the farm input industry are forward integrating into distribution to insure economies of scale (Minden, p. 678) and, in some cases, to combine products for synergistic sales purposes.

The fertilizer industry is a major exception to this generalization. During the 1960s a large number of firms entered different levels and areas of the fertilizer business. Production expanded and economies of scale were realized in larger plant sizes. In addition, established firms were for the most part back integrating or adding new product lines; actual new entries were dominated by conglomerates (U.S. Department of Agriculture).

To further illustrate the degree of competition, cooperatives hold significant shares of the market in a number of segments. In five major segments, feed, fertilizer, petroleum, seeds, and pesticides, cooperatives held 18% or more of the market during 1970 (Abrahamsen, p. 10) and the trend would indicate even larger shares in the future. The exception is the farm machinery and equipment industry where cooperatives hold only small shares of the market.

Very little literature exists on how prices are determined in the farm inputs industry. Some popular publications do indicate that prices are based on cost plus a markup with adjustment being made for demand and supply factors and "what the competitor might do."

[1] Farm credit is not considered in this paper since the forces affecting credit costs and availability are much different than those affecting other farm inputs.

Due to market concentration and probable pricing policy, a large part of the farm inputs industry can likely be characterized as oligopoly-like where the edge of competition is sharpened by cooperative involvement. Yet, the potential noncompetitiveness and market power implications have drawn Dahl and Mather after a thorough study of the organization of the farm input industries to recommend the following:

> We recommend that (1) our antitrust laws be redrafted to stem the tide of vertical and conglomerate growth and mergers and the ever-increasing market power of the farm supply cooperatives, (2) our producer and consumer protection laws be coordinated to reduce red-tape and encourage reasonable compliance, that price reporting for inputs be developed, and that grades and standards for farm inputs be studied as a way of improving farm purchasing decisions and (3) U.S. agricultural policy be coordinated, especially domestic programs and international trade developments, only after careful analysis of their impact on farm input industries and the availability and prices of supplies to the U.S. farmer. (P. 5)

If carried out, the recommendation above would be far reaching and would cause changes that would flow through the entire food sector. A number of questions arise as to what are the implications of these recommendations as far as technology adoption rates, efficiency, and sector growth. Another concern is to determine whether price changes in food at the retail level could be passed back through the farm producer to the farm inputs industry.

The Farm Producer

A decade ago most agricultural economists would have agreed that farm production represented a reasonable likeness to the purely competitive model. Now that concept is not approached with as much certainty, especially if projected to the future. In a recent study Heid explains that "farm production is becoming less characterized as a large number of small units operating in a purely competitive environment. Many farms are becoming larger and more specialized. The emerging group of large farms, although relatively small in terms of numbers, is larger in terms of the proportion of land control and total production. Incorporating integration, and contract buying have become somewhat more prevalent. For some commodities these trends have advanced further than for others" (p. 1). Causal factors related to the growth in farm size and decrease in farm numbers is to some extent speculative. Conventional knowledge places returns to scale as a major factor. Seckler contributes growth in farm size to the drive to attain a "decent living" by the farm producer. "Note that this growth in average farm size has occurred with constant return to scale and no necessary change in unit costs of production. All that has changed is the socially accredited magnitude of a decent standard of living. The hypothesis is that farm size will grow at a rate commensurate with growth of average family income in the economy as a whole" (p. 15).

The Seckler hypothesis is to some extent substantiated by Krenz, Heid, and Sitler in a study of large farms in which they conclude that before-tax returns are greater per acre as well as per dollar invested due to volume price premiums for products sold and volume discounts for products purchased. After-tax returns were similar due to the progressive nature of state and federal income taxes (Krenz, Heid, and Sitler, p. ii).

The potential for reduced competition in the longer run may exist due to increasing farm size. However, one important barrier must be overcome, decomposing the husbandry function performed by the individual farmer into specialized functions performed by several individuals in order to obtain further economies of scale (Seckler, p. 15). Even then corporate farming must grow substantially since "only 1.2 percent of commercial farms in the U.S. are incorporated and nine-tenths of them are merely family-owned businesses . . ." (Coultz, p. 136). In the shorter run, reduced competition may exist due to governmental supply management programs being introduced if world demand for agricultural commodities and prices recede below target prices and possibly loan levels. Under the Agriculture and Consumer Protection Act of 1973, the Secretary of Agriculture has the authority to impose production controls over individual commodities.

In this setting farm size will not only increase but farm producers will further integrate production and marketing components. Nobe argues that these steps are necessary for survival of farm producers. The most recent food commission studies suggest the alternative of farmer marketing boards. Several forms of forward integrating may partially solve the farm producer's problem of gaining market control, but this alternative does not

solve the problem of responsiveness to the consumer. Hildreth, Kraus, and Nelson note that a resultant organization "must not be grossly inconsistent with the broader objectives of the society of which it is a member" (p. 858).

Due to the structural changes just described, as well as a wider dispersal of smaller processing plants, changes in transportation means (rail to truck), faster communication systems, and uniform grades and standards, Courtney and Forker conclude:

> Three general types of pricing arrangements appear to be evolving: (1) sole reliance on individual negotiation, (2) a slight modification with group negotiation and (3) some form of corporate or governmentally administered pricing. One might think of these as a continuum of alternatives with individual negotiation the rule in situations where individual firms are faced with perfectly elastic demand curves. Groups of firms getting together to negotiate would imply movement towards demand curves that are somewhat less than perfectly elastic. Corporate-administered prices would imply less competition and the ability of firms or groups of firms to set price and adjust production to satisfy demands at that price and, of course, to adjust price as seems appropriate for their best interests. Governmentally administered prices would be an attempt by the agricultural sector to achieve a monopoloid position in the pricing of their commodities. All are possible alternative futures. (P. 15)

The last two alternatives listed would imply a reduction in competition in the market place where the farm producer interfaces with the food processor, the food retailer, and ultimately the consumer.

No recommendation or alternative is considered here except that the information base on prices as reported by governmental and private sources be expanded to include forward contract prices—a growing price arrangement as farm size increases. It is thought that the previous recommendation as well as alternative recommendations that follow for the food processing and retailing industry would substantially alter the evolving pricing arrangements as well as the competitive structure of the farm producer.

The Food Processing Industry

The food processing industry contains many levels of competition.[2] Greig delineates two major processing layers that have distinct competitive characteristics. The first layer —commodity processors—is considered as nearly atomistic, producing products that are homogenous. Commodity processing examples include the canning and freezing industry which produces fairly standard products. In addition, technical, research, development, advertising, and promotion requirements are low—there are few barriers to entry. Margins are low and competition is keen. On the other hand, "packaged goods" processing is oligopolistic. Processing results in readily identifiable products and entry is restricted by relatively high research, development, advertising, and promotion costs.

Keeping in mind the delineation above, the food processing industry is following a trend of vertical integration, conglomeratization resulting in decreasing numbers of firms and plants (Araji and Roetheli). Forward contracting is common both for purchased inputs and products sold. Except for the first layer of commodity processors who interface with the farm producer, the remainder of the industry appears similar to the oligopoly model. But it must be admitted that the food processing industry concentration is low in comparison to other nonfood industries.

Further exceptions are that the industry as a whole in the past has maintained relatively low returns on capital employed compared to other U.S. industries. Probably because of low returns, the industry has maintained comparatively high equity positions and the industry was relatively reluctant to use capital leverage as a means to attain growth. High equity positions also made them more subject to acquisition by conglomerates. Therefore, it appears that the food processing industry tends to use only muted oligopoly market power. Instead, oligopoly positions of such firms were used as security that diluted their desire to take risks on new ventures—a characteristic that may not be entirely detrimental to consumer welfare.

The Food Retail Industry

The food retail industry is characterized by trend decreases in the number of firms and an increased share of market held by larger firms. The concentration trend is even more appar-

[2] The food processing industry is of particular current interest due to the Federal Trade Commission action against the ITT Continental Baking Company on the basis of anticompetitive practices. Through the action, the Commission is seeking to require ITT to divert some plants and license brand names and trademarks to other bakers.

ent at the regional level. However, the total number of food retailing firms is still relatively large. The top fifty firms in terms of total sales hold roughly 44% of the grocery market, a share that has gradually increased from about 37% in 1964 (*Progressive Grocer*). Market shares based on the grocery market can only be roughly approximated because the items included as "groceries" vary. Leadership in market share growth has not been assumed by the largest firms. Of the top fifty firms, the smaller thirty firms in that group have taken leadership in market share growth since 1965.

Under this form of concentration it might be assumed that the largest firms would practice price leadership. But this result has not occurred. As indicated earlier by Nelson and Preston, all firms in the industry are capable of being "price initiators" (any firm that happened "to lead off a particular sequence of price changes") while no firms seem capable of being "price leaders" (firms "that regularly and consciously assume the role of price initiators") (p. 97). A firm in one region initiates a new price policy and only its nearest competitors are concerned. In some cases the nearest competitors simply "ride out" the effects of the changes in initiator prices, expecting either no effect on their customers or a reversal of the new price policy. Price competition in some cases appears in more subtle forms of pricing. An example is variable price merchandising (Nelson and Preston).

Economies of Size and Pricing

The characterization above contains many exceptions because the food sector is a mosaic of industries formed by chance, growth, and merger. In some cases growth and merger were based on economies of scale and in other cases on simple pecuniary interests. At this time it is impossible to ferret out the exact amount of benefits derived by consumers from economies of scale let alone whether they are due to labor specialization, engineering efficiencies, or "economies of massed reserves" (Robinson, p. 26). However, the current concentration levels and the pricing policies lead one to believe that losses to the consumer could be substantial. Most of the food industries at the retail, processing, and farm input area are large enough that they have lost sight of the profitability of the numerous individual items sold, so that decisions as to resources to allocate to individual products cannot be made adequately. Most firms have at least several plants producing the same products, indicating that limits to economies of size have been reached at the plant level and require another layer of middle managers to coordinate the production and marketing from various plants. Most corporations are large enough in the food sector (except at the farm producer level) so that they are divided. In this arrangement, prices of inputs produced by one division and used by another are determined by interdivisional negotiations (Carley, p. 1; Menge, p. 217). As a result, without market prices there are blind spots in the information flow that may lead management to misallocate resources. Finally, most firms have gone to central distribution centers that are bottlenecks if additional plants or retail outlets are brought on stream.

Earlier evidence indicated that firms under the control of professional management, as opposed to ownership control similar to most large food firms, were less aggressive. More recently this concept is questionable since no substantial difference is observed between owner-controlled and manager-controlled firms (Palmer, p. 293; Kania and McKean, p. 10).

Pricing policies of the food sector range from cost plus for the farm input industries to various semicompetitive practices at the retail level and no single oligopoly-like pricing model fits the situation. From a broad standpoint, though, "any realistic theory of oligopoly must take as a point of departure the fact that when market concentration is high, the pricing decisions of sellers are interdependent and the firms involved can scarcely avoid recognizing their mutual interdependence" (Scherer, p. 157). Further, it appears that firms at the retailing and processing level can pass costs back to the farm level if they cannot pass them forward to the consumer.

A confounding issue on pricing in more concentrated industries is that the most concentrated portions of the food industry, like the ready-to-eat cereal group, tend not to raise prices as much during inflationary periods as less concentrated industries, like the meat processing group, but overall their price margins are higher than those of less concentrated industries. Apparently, more concentrated industries with more control over their prices are able to push prices up steadily—even as inflation recedes and as demand falls. Thus,

they are able to gain higher margins without excessive price increases over cost during inflation, but they provide the support for sustained chronic inflation. Even in this setting, though, it appears that without strong competitive forces, price increases can be passed along to the consumer, especially when coupled with some evidence that demand for food in the U.S. has increased considerably over the last few years and consumers have apparently become less sensitive to prices (Walters and Moore).

As is the case with the food processing industry, the food retailing industry might appear to fit the oligopoly model, especially at the regional level, but whatever market power advantages food retailing firms might have appear to be focused more on activities that would enlarge or enhance their physical capabilities and the market areas they serve (which may include closing smaller stores).

Summary and Suggested Alternatives

The competitive model that fits the food sector is at best vague. Essentially, each segment, farm input industries, farm producers, food processors, and grocery retailers, is characterized differently with major exceptions in each case. Overall, with considerable reservations, the farm producer can be classed as competitive with a growing tendency to assert market power. The farm producer interfaces with the farm input industry and the food processing industry, both classed as forms of muted oligopolies. The retailer, who is the final link to the consumer, is still one among many at the national level but can and does still hold oligopoly powers at the regional level.

In view of the food sector's current muted oligopoly structure (except the farm producer) and the trend to more concentration, several alternative remedial policies seem apparent: (*a*) vigorously using antitrust legislation against mergers that have led to further concentration by the largest firms, (*b*) redrafting of antitrust legislation to allow decentralization of heavily concentrated food industries, and/or (*c*) extending the graduated federal income tax to levels beyond 48% at the $50,000 before-tax profit level. The alternatives represent a continuum of control over oligopoly practices from a weak control over anticompetitive practices and centralization in the first alternative to direct disincentives for bigness in the third alternative.

The first alternative to some extent is being practiced now with the recent indictment of ITT Continental Bakery, the price fixing charges being brought against several sugar companies, and at least the investigation of the ready-to-eat cereal industry in which four companies hold 90% of the market. At best the prevention of mergers and foothold acquisitions could only partially prevent further concentration. Through internal growth and the gradual decline of other firms in the food market, more concentration could still occur. The inability of this alternative to halt concentration or cause dissolution probably makes it a weaker means for slowing inflation caused by concentration.

Under present law it is not feasible on a broad front to require the dissolution of oligopoly firms (McLaren, p. 107). Under section two of the Sherman Act, firms can be required to deconcentrate if they have attained or maintained monopoly power by improper means. In other words, if firms have obtained oligopoly status by growth that has not depended on merger, pricing policies that do not prevent new entry or eliminate competitors and sales policies that do not tie major parts of the market to them, they are not subject to antitrust prosecution. Further, when anticompetitive cases are won, the courts are reluctant to grant dissolution due to the effects of disrupting the market and the problem of "unscrambling" two or three firms in terms of employees, assets, and customers. Under these circumstances in order to achieve deconcentration on a broad front, it would be necessary to redraft antitrust legislation to more strongly restrict anticompetitive forces and to allow dissolution. Two approaches could be taken, one that allows careful consideration of each segment and each level of the segment and the other that insures that strict numbers of firms and shares of the market are adhered to. Carefully considering each segment and level would be more fair since the institutional setting and the nature of the business causes the parameters for competition to change. Consideration of each segment of an industry seems necessary since there is a considerable conceptual difference between monopoly or oligopoly power and "bigness." Some firms, such as Ralston Purina which produces ready-to-eat cereals besides many other items, may be big but have very little

oligopoly power in the ready-to-eat cereal market. The strict numbers of firms and market shares approach is neat, simple, and fairly brutal. Further, it would probably result in a number of constraints on the market that would be more costly than those currently due to the muted oligopoly effects.

The third alternative of extending graduated corporate federal income taxes attacks bigness per se and could induce dissolution of large firms as well as offer a continuous incentive for avoiding increases in size (Simon). This alternative would relate to bigness per se and would be applicable if it is believed that too much social control is in the hands of too few firms. As suggested by Simon, the tax could be implemented gradually over time but within limits so that corporate taxes would not exceed federal income taxes to the individual. So as not to disturb smaller corporations, taxes higher than 48% might not be increased except for firms in the \$80 to \$100 million before-tax profit range. The graduated federal income tax alternative for levels beyond 48% would reduce the incentive for further concentration and give smaller firms a competitive edge. The disadvantages of this approach are that some large firms might succeed in passing the taxes on as price increases to the consumer. Further, if applied quickly and in a "once and for all" procedure, it could have a detrimental effect on the national economy.

Further Research

The current level of knowledge does not adequately indicate the detrimental effects of concentrated structure nor does it detail the benefits of large resource concentrations. Both factors would be useful in determining appropriate policy measures for the food sector. However, determining costs and benefits of concentration is dependent on accurate cost and price information. Due to the vital link between increased concentration and inflation, it seems to the benefit of the public that large industry concentrations be required to divulge price margins, costs, etc., by product line so that policy makers and economists could more accurately determine beneficial policy alternatives. The difference between estimated margins and actual margins are often substantial (Braunschweig). As suggested by Hildreth, Krause, and Nelson, possible research through a "National Institute for Food and Fiber Research and Education" may be in order. However, the task should not be "to provide the guidance which subsectors will require to invent much of their future economic organization . . ." (p. 858). If subsectors are left to their own devices (with or without guidance) to invent much of their future economic organization, it seems abundantly clear that they will select more concentrated power. Passive guidance will not do. Guidance with "clout" is necessary.

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Emerging Effectiveness of Competition and the Need for Consumer Protection

D. I. Padberg

This paper has the following objectives: a long-range view of structural change in the food industries, an update of market performance expectations, an assessment of important performance problems in the food industry and some observations on the kind of public bureaucracy needed to protect consumers' interests. Where the discourse follows industrial organization conventional wisdom, I will make it as brief as possible. On the few occasions where it is necessary to leave the well-worn path, I will attempt to detail the landscape more fully.

A Long-Term View of Food Industry Structure

Food industry structure is a mosaic of the following kinds of firms: food chains, group wholesalers, independent retailers, independent wholesalers, food brokers (and some other small middlemen), small food manufacturers, large conglomerate food manufacturers, and the few cooperatives at the farmer interface as well as at the consumer interface. Most of these types of firms (and certainly the large majority of their numbers) are small in size and price takers in behavior. The largest of the food chains and the conglomerate food manufacturers have "big business" organization and patterns of initiative and strategy unique to their structure. They represent a considerable departure from price-taker behavior. In the case of the food manufacturer, the nature of this departure is quite in the direction of conventional oligopoly behavior. Oligopoly, a characteristic structure and behavior within a market, is an inadequate characterization, however, because both the structure and behavior of these firms cut across many markets. Also, their tendency to offer a constant stream of new products means they are operating between organized markets. This syndrome is more Galbraithian than oligopolistic.

In the distribution system, the largest firms are often called a distribution oligopoly, although their behavioral tendencies are at best mixed and for the most part very different from the conventional manufacturer oligopoly. The most outstanding feature of these largest distribution firms (such as A&P, Safeway, etc.) is their integrated supply system and merchandising emphasis on private label products. Unlike manufacturer oligopolies, products that bear their label have an economical image. Rather than having a head-on collision as might be suggested in bilateral oligopoly, the power blocs in these industries tend to avoid each other and pursue the strategy of their preference. (This interaction pattern is identified and related to food industry data in Handy and Padberg.) The largest food chains display products of the large conglomerate manufacturers at higher prices to give their customers variety but also to make their private label products appear to be a good value. While they stock many national brand products, their merchandising emphasis is on selling their own labels.

Large manufacturers find their most attractive outlets, particularly for new products, among the smaller retailers who do not have a powerful integrated supply and the price advantages associated with it. These small firms need the marketing razzmatazz and presold products coming from the large manufacturers. The small distribution firms may offer private label as a way to extend product variety to their customers, but their merchandising emphasis is clearly on product excitement, new product introduction, and activities compatible with the competitive strategy of the large manufacturer.

It is useful to look at the evolutionary pat-

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terns through which these structural types have emerged as a way of gauging the structural change we might anticipate in the future. At the distribution level, the structural types are quite mature institutions. The food chain emerged and went through considerable experimentation in the last century. Its adoptive phase was primarily between 1920 and 1930 (Padberg 1968). The reason for its emergence was primarily the need on the part of food manufacturers and importers for distribution services of a more orderly character than were available in the market. The general focus of operation was in preretailing activities including wholesaling, manufacturing, transportation, storage, etc.

The supermarket came into the distribution picture in the 1930s and was rather completely adopted twenty years ago. The reason for the supermarket was the shift of the population to suburban living patterns (as well as rising income, automobile adoption, etc.). Until we have a new pattern of living, perhaps more urbanized, the supermarket is likely to continue as our major form of food distribution to consumers. While it is fascinating to ponder the next demographic shift, it is likely a long way away (Padberg 1971).

The evolution of food manufacturing institutions is somewhat different and generally more complex (see Buzzell and Nourse; FTC 1962; Greig; Nelson and Britt; Padberg 1974). At the turn of the century most food processing was done in the household. Even in the factories most activities were done by hand. Around this period, however, most processes were being adapted to machine operations. Accompanying this transition firm structure moved from many small firms to fewer and larger firms still processing usually a single product and adjusting to a size sufficient to accommodate new machinery. This process continued through both world wars and led to many regional food processors.

The next major change was the consolidation of many regional processors in many different lines into the conglomerate food processor of today. This transition occurred to accommodate centralized marketing activities. The onset of television, rapid rises in income, and changes in life style created an opportunity for marketing convenience-type food products which required more processing and which sold for higher prices. The national structure, crossing many commodity lines, was much more competitive and powerful in this marketing process than the smaller, regional, single commodity organizations they replaced. This transition period may be called the "marketing revolution," because the major impetus for structural change was in marketing activities rather than in processing technology as the previous one had been. The peak of conglomerate acquisition activity occurred in the late 1960s (Nelson and Britt; Padberg 1974).

Unlike the major structural changes in food distribution, these changes in the manufacturer structure are very recent. The conglomerate merger movement continues, although at a much lower rate than six years ago. What is the eventual meaning of this transition? What should we expect of this new kind of large firm? Analysis of previous structural transitions in the food industry (the food chain, the supermarket, manufacturing plant consolidations) has been reasonably well guided by the theory and tradition of "Industrial Organization." The analysis of the conglomerate food processor, however, is plagued by conceptual and other problems: (*a*) most of our data sources pertain to either firms or industries (we need data on subsets of activity within the conglomerate firm, i.e., the "Armour" part of Greyhound, the "Continental Baking" part of ITT); (*b*) the extensive use of advertising may affect public values as well as purchase decisions; (*c*) while some consequences of these large institutions may be very long-run in character (*b* above), our observation period is very short; and (*d*) the theory and tradition of industrial organization falls short of providing an adequate conceptual framework for analysis. While it is not possible to immediately treat all of these matters, a minor overhaul of our view of economic performance seems most helpful.

An Expanded Conception of Performance

Bain and others have used a conception of market performance as a fundamental element in the industrial economics framework (Bain; Scherer; Sosnick). "Market performance refers to the composite of end results in the dimensions of price, output, production costs, selling costs, product design, etc., which enterprises arrive at in any market as the consequence of pursuing whatever lines of conduct they espouse" (Bain, p. 11). This and other

usual definitions of results seem to relate to events in the market, to elaborate several quantitative dimensions, and to include a reference to some qualitative dimensions as well. Research studies following this lead have in fact used the market as a frame of reference. They have directed a great deal of attention to the quantitative dimensions (price, output, production and selling costs, profits, etc.) and virtually disregarded the qualitative components. In fact, Bain addresses ten times the space to quantitative matters than is allowed for a few judgmental remarks concerning the qualitative aspects of performance.

This tradition helps us very little in dealing with the conglomerate firm. These food processors are not organized to be sensitive to the nature of particular markets but to project a centrally organized pattern of strategy across many markets. The focus of their competitive activity is the qualitative aspects of products not the quantitative aspects. The rivalry among these firms is not the repetitive creation of known products but a "process of experimentation" with product characteristics and images. This process of experimentation consumes vast amounts of resources. It changes our life style by making different products available and perhaps by changing our values. These are outcomes of present economic activity within the food industry that are important to the public welfare. They do not particularly fit the tradition of industrial organization analysis.

The concept of the market is not only strained by the structure of the conglomerate firm; the introduction of a new product strains the concept of a market as the basic frame of reference. What is the market for a new product? What market setting identifies the forces of competition influencing a firm which chooses to continually alter physical and psychic characteristics of consumer products? Our inherited conception of a market can place the traditional quantitative variables in some meaningful relationship to each other. Is this inherited concept useful in assessing the meaning to society of a process of experimentation?

It seems there is a need for an expanded concept of results which might be called "microeconomic performance." This implies a broader frame of reference than a market and might involve a pattern of interactions which related activities in many markets. On the other hand, this conception of economic performance does not deal with or relate to macro-objectives such as employment, stability, etc. It is recognized that microeconomic performance has important quantitative and qualitative dimensions. The quantitative dimensions need no elaboration as they have been faithfully pursued by Bain; Sherer; Marion and Handy; and Sosnick.[1] However, the important qualitative dimensions need further elaboration because no one has pursued them.

Qualitative change in production processes may be important to firms, but it offers no great conceptual problem. While it is an experimentation process, results are objectively definable and measurable. These objective and measurable consequences need only to be apparent to a few experts for this type of progress to occur. Qualitative change in product characteristics is much more difficult. Progress is not definable or measurable. Great expenditures may be required to convey information and imagery about the product. Side effects of this process may have important influences on consumers' welfare. The most fundamental question is whether to allocate resources to this process of experimentation. If so, how many resources should be allocated as compared to those allocated to producing conventional products most efficiently? My choice of a mechanism for making this allocative decision is the consumer. This would require that conventional products be readily available at lower prices commensurate with the lower cost of their repetitive mass production. New products would be available at the higher prices required to cover the higher costs of the process of experimentation and communication. Consumers would need to understand the nature of the choice offered them.

The second dimension of product progress is product safety. When the physical characteristics of a product are being purposely and experimentally altered as a primary focus of competitive activity, the question of product safety moves to the center of the stage and must be taken into account. Product safety refers to the manipulation of physical characteristics of the product, and it is particularly important in an industry such as the food industry. Not only are the physical characteristics of the product directly related to nutrition

[1] Clearly Sosnick and, to a greater extent, Marion and Handy have demonstrated sensitivity to the qualitative dimension of performance. Yet, the result is insufficient to provide substantial priority and does not begin to identify important elements. Also, the preoccupation of both these constructs is with markets.

and health, but adverse effects may not be discernible immediately. Therefore, experimental features constitute a long-range hazard and an element of risk difficult to measure.

In addition to experimenting with products' physical characteristics, this performance dimension involves manipulating the basic meaning or imagery the products convey. This may also influence the public welfare. By promoting sweetness as a desirable characteristic of cereal, we may set up dietary patterns, especially in children, which are inimical to the public interest. By advertising automobiles as symbols of power and aggressiveness, we may waste fuel resources while increasing the slaughter of our citizens. While this performance issue is very much like product safety, it is much more complicated because it deals with psychic or attitudinal product features rather than their physical properties. We will call this phenomenon "constructive product image."

Deception in advertising has long been recognized as an important matter in protecting the consumer interest. It continues to be important for the usual reasons but attains a bit more importance when associated with the process of experimentation with physical product features and product images. With product features and images in a state of constant change, it is more difficult to tangibly identify deceptive and misleading claims. Yet, it is all the more important that information about new product choices be valid and understood if consumer sovereignty is to have meaning. However, advertisements should not just be undeceptive; they should also make some minimum positive disclosure. We may call this "adequate consumer information."

In identifying an expanded concept of microeconomic performance, it is not my intention to suggest that quantitative matters are trivial, but rather to recognize the parallel importance of qualitative changes in products and processes and the significance they have for consumer welfare as well as motivations within the industrial structure. While satisfactory operational definitions may not be possible at this point, at least we can start recognizing the topics. This first effort might look something like the following:

Microeonomic performance

- A. Quantitative dimensions
  1. Production efficiency
  2. Profit levels
  3. Selling costs
- B. Qualitative dimensions
  1. Availability of economy alternative
  2. Product safety
  3. Constructive product image
  4. Adequacy of consumer information.

Assessment of Food Industry Performance

When we appraise the performance of the food industry in the quantitative dimension, the results are reasonably good. This is not particularly surprising in an industry in which the large part of the firms are atomistic price takers and in which one of the clusters of big business structures (the distribution oligopoly) is motivated by price competition. The large size of the food industry tends to make the relative position of fairly large firms less dominant. Despite these generalities, a need continues for surveillance and antitrust attention to issues involving quantitative performance (price, quantities, etc.). (See recent cases, for example, in *Supermarket News*.) There is very little new on this frontier. The kinds of problems we're dealing with are the kinds of problems we have been facing for decades. The type of governmental structure which has evolved to address these issues seems generally appropriate. I would view consumers' needs in the future to continue very much in the tradition which has been developing over the past decades.

If one were to appraise the nature of performance in the qualitative dimension, it is possible that the food industry would look reasonably well. If that is true, it is primarily a coincidence or a result of the munificence of private institutions involved in food manufacturing. Certainly we have not gone very far in defining the public interests in this area. Our public policy has for the most part ignored it. We have neither the conceptual basis for identifying the public interest nor a public bureaucracy capable of implementing or enforcing it.

How much does it cost to perform this process of experimentation? Are the physical characteristics of these products consistent with the public interests? Are the psychic or imagery characteristics of these products compatible with the public interests? Is com-

munication insufficient or misleading? These answers need to come into the focus of research activity as well as public policy on behalf of the consumer interest.

The cost of experimentation must be quite high. The inherent economic implication of experimenting with product characteristics draws primarily from the dividing up of large volume product flows into many experimental rivulets. Considering the automated type of processing, storing, transportation, distribution, and sale to consumers, handling a given volume in many different lines rather than one line must increase costs. Start-up costs alone are significant in processing but the start-up cost of getting consumers to try a new product is vastly more expensive.

There is no question but what we could produce and distribute standard products at a considerably smaller cost than that which we have incurred from a constant and intense process of product experimentation. Work done by the National Commission on Food Marketing indicated that on the average private label products sold for 20% less than national brand competitors (Padberg 1968, p. 93).[2] While this measure may not be a precise indication of the added cost of experimentation including technological and advertising involvement, it is likely a good approximation. Twenty percent difference in consumer price is a substantial magnitude in an industry sensitive to very narrow margins associated with high volumes. This magnitude represents about 50% of the value added within our food dollar by the farmer.

We probably have a much better indication as to whether this activity is consistent with the public interests and consumer preferences than is the case in other industries. We have a distributor structure motivated to produce and make available private label products which de-emphasize marketing activities and give consumers an opportunity to choose between the economy product and its "jazzed-up" rival. That choice is probably much more available in the food industry than in many other industries. Despite the availability of an economy alternative, food manufacturers emphasizing changing product characteristics particularly in the direction of convenience foods have had a real and direct impact on consumers. In the past fifteen years our life style has changed markedly—rising family income has created a very different pattern of work in the kitchen (Padberg 1970). The efforts of the food manufacturer to find, by experimentation, effective new convenience food products has probably been consistent with the public interest and consumer preferences.

What is likely to prevail in the future? Will an optimum balance between experimentation and economy products be found automatically? Do consumers understand the availability of the economy alternative? If we are going to condone a large component of experimental activity, it seems appropriate that the public should insist on a series of safeguards. It is my judgment that we have done poorly in this regard in the past. Private labels have not been recognized as economy alternatives but have sometimes been criticized as structural and performance failures (FTC 1962, p. 92).

Product Safety

Product safety in the food industry is primarily the responsibility of the Food and Drug Administration. Other agencies, particularly the Department of Agriculture, have some responsibilities in this area. Nonregulatory groups are also involved, including the Food and Nutrition Board of the National Academy of Sciences. There is no question that the experimental activities going on in the food industry put tremendous pressure on the surveillance and regulatory functions. Standards of effective regulations are extremely difficult to identify and I have little to add or suggest in this area. The presence of a health food industry promoting organic food and claims linking food additives with hyperkinetic behavior in children suggest the pervasive nature of this responsibility. There is a need for positive communication with the consuming public as well as orderly surveillance and regulation.

Constructive Product Image

Food is coming into quite a different role in American society than was the case a generation or so ago. In a subsistence society, food is an important part of the total consumptive activity. Changes in household well-being is

[2] Scherer asks quite a different question—something like "How much is the quantitative performance of the economy affected by market power?"—and comes out with a guess of 6.2% in 1966 for the whole economy (p. 408). The costs of product experimentation may be much greater than what we can associate with monopolization. Yet, we have no framework by which to assess what is good and bad about it.

often extensively reflected in the nature of available food. The celebration of food is not only important in our American heritage but is probably even more developed in European cultures. The presence of a larger and more developed "idle rich" component of European society has tended to magnify the extent to which the celebration of food is observed. Against this heritage, the household of the 1960s shifted its priorities toward activities outside the household including employment, volunteer work, civic concerns, recreation and leisure activity, creative and self-fulfilling pursuits, etc. This change of priorities was stimulated by rapid rises in income and education. As a consequence, food has become less central to our view of life. No longer a cause for celebration, eating has become a maintenance activity.

It is most difficult to judge the role and significance of advertising by the manufacturers. It is presumed that this advertising activity is in the interest of the seller of these products. It may also be presumed that it is in the interest of the consuming public as well.[3] However, many questions are left without answers. For example, how important is planned obsolescence? How frequently do food ads contribute to dietary habits which are detrimental to our collective nutrition? How often do we develop imagery that is basically wasteful of natural and other resources? Many media communications are exploitive of fundamental human motivations, particularly sex. What effect does this activity have on our ability to live happily as a society?

My own judgment is that the process of experimentation in new foods attended by and perhaps led by a new and evolving image of food has been primarily a reflection of the public interest as it would be described either by laymen or experts. I think this is particularly true for the past two decades. This period included monumental increases in real income and significant changes in life style. The wide open and flamboyant experimention was a natural accommodation of this basic societal transition. It may be much less valid, however, to assume that untrammeled experimentation centered around the interests of large firms will be in the public interest in the decades to come. I believe that life styles will be changing less rapidly, that economic growth in real income will be very small, that conservation of resources will assume a much higher national priority. Further, I am a bit anxious and concerned that we have no public policy in this area where the public interest seems tremendously involved.

Beyond having no public policy there exists no conceptual basis from which a public policy might emerge. In order to have public policy concerning the psychic or imagery dimensions of new products, we must be able to set some limits on message content in advertising. In our present tradition, the Federal Trade Commission is primarily responsible for the public policy governing the media or other means of promotion. This tradition has centered around the matter of deception. We do not have a basis for saying what images are consistent with the public good; we merely make judgments about the extent to which they may be deceptive or misleading. We tolerate advertising sweet cereal to children that no one would argue has any consistency with the public well-being. We just have no basis for intervention on this subject of message content.

Why do we consider the airwaves private property? It is certainly not by logic—it is primarily by tradition. When the factory was first invented, it too was seen as an entirely "private" phenomenon. It took us, as civilized beings, perhaps one hundred years to get around to passing child labor laws and other instruments through which the public interest dimensions of the factory were recognized. We eventually got around to providing guidance to make results fit our conception of the public interests. Television is new in history. The marketing revolution which transformed regional processors into national conglomerates is a postwar event which reached its peak in 1968–69. We haven't had much time to work out the public interests involved in these image oriented activities. I hope it won't take a hundred years.

Adequacy of Consumer Information

Information adequacy is a close relative to deception. It is turned a different direction, however. The question becomes "Is the information available to consumers sufficient for society to make informed choices?" rather than "Can this or that claim be supported?" We have some experience in requiring the disclosure of significant information as a part of

[3] Oddly enough, research about advertising rarely addresses these questions. Usually it assumes advertising is a sales lubricant and measures its functional efficiency (Borden; Padberg 1972b).

an anti-deception policy (Troelstrup p. 249).[4] However, a concept of "adequacy" is neither defined nor enforced.

A Public Technostructure

We are able to cope with the various quantitative aspects of market performance reasonably well. By chance and on a hit-and-miss basis, we monitor some of the effects of qualitative change in products as well. Taken as a whole, however, neither our concepts nor our public bureaucracy are sufficient to deal effectively with the issues coming from the process of experimentation and qualitative change in products. We have considered this economic activity not all that different from the repetitive creation and distribution of known goods and have applied traditional concepts and enforcement procedures. I argue that the qualitative aspects of market performance are different in kind from the quantitative and that they require a different array of definitions and concepts as well as a different type of enforcement bureaucracy.

Galbraith's imperatives of technology detailed some of the different and unique characteristics a firm takes on when it changes from the repetitive creation of known products to a process of experimentation with more complex and sophisticated products (chap. 2). These imperatives have implications for firm structure favoring very large size. Financial planning becomes a much more crucial and significant part of firm growth and competitive strategy. Marketing activities, including intensified communications with consumers, are important. But perhaps of greatest interest is the phenomenon of multidisciplinary cooperation. This body of knowledge, and the ability to acquire knowledge on many particular subjects, is embodied in people whom collectively Galbraith calls the technostructure. It is this force which makes the qualitative aspects of economic performance different from the repetitive creation of known products. It is this force that has an impact on our values as well as our indifference curves. This force affects the public well-being, but we don't have any organized conceptual framework for defining the public well-being or enforcing rules to enhance it.

[4] This is a very constrained "advertising content policy." The strategy of the FTC was to use their power to "compel affirmative disclosures of strategic product information that is inherently deceptive when omitted from advertising" (FTC 1969). Even this weak policy has been little used. With the most vigorous use, it does not address the antisocial cereal or auto.

Protecting Consumer Interests

At this point I would like to urge the creation of a multidisciplinary consumer protection agency. I would like this agency to have the resources (intellectual as well as financial) for identifying and defining societal problems attendant upon the experimentation process in food and other products. As indicated above, I think the main problem areas would seem to be assuring that (*a*) the consumer has a way to choose the traditional product instead of the new one, (*b*) the experimental products offered are safe (physical properties compatible with public interests), (*c*) product images are compatible with public interests, and (*d*) private sponsored information flows (advertising) are accurate and sufficient to enable the consumer to make an informed choice among offerings. It seems to me that all of these matters are part of the single, dynamic process and they should be treated as such within the public agency just as they are in private, large firms.

Traditional, quantitative problems associated with consumer protection have been relatively straightforward, simple, single-dimensional issues. Society has approached them in a very disorganized way. A consumer movement has waxed and waned down through the decades reaching peaks of effectiveness and declining into nearly complete inactivity (Herrmann; Mather; Padberg 1972a; Troelstrup). This movement has given basis for quite a number of consumer protection laws and policies. These laws in turn have been enforced by attorneys. Where the laws have been inadequate to the job, they may come up for modification in the next peak of consumer movement effectiveness. This system has been an effective approach to the quantitative, single-dimensional problems of central importance in the past. This frame of reference and method of operating still works with reasonable effectiveness for the quantitative problems of the present and is likely to be effective in the future.

There is some evidence, however, that this societal approach does not work very well on the very complex and multidimensional problems associated with qualitative change and experimentation. In order to illustrate this

matter, I would like to present a contrast between the Fair Packaging and Labeling Act of 1967 and the Nutritional Labeling Program of the Food and Drug Administration promulgated to take effect July 1975 (Ayres and Padberg).

A study of the policy formulation process associated with the Fair Packaging and Labeling Act of 1967 commonly known as "truth in packaging" paints a vivid picture of the inability of consumer advocates (motivated primarily by principles) to come to grips with a matter as multidimensional and complex as packaging. In addition to pure principles, sufficient knowledge of industry operations, consumer preferences, food science implications, and packaging technology must be available to enable the integration of principles into realistic policy rules. That is a very multidisciplinary need which could not be fulfilled by the intellectual and informational resources of the consumer movement. As a result, they transcribed an exercise in futility through a period of several years. They produced a law which made no sense and was essentially an appeasement. It never reached any significant degree of implementation, which is a reasonable test of its usefulness.

In contrast, a program on nutritional labeling is already going into very widespread implementation. The nutritional content of formulated foods and other foods about which nutritional claims are made will be identified on their labels in a standardized format. Research on this topic suggests that we may expect rather profound results of this implementation (Lenahan et al.). The disclosure of nutritional information for the first time will undoubtedly create a degree of nutritional awareness and sensitivity on the part of consumers but, perhaps more important, on the part of manufacturers. I think these complex technostructures involved in the process of product experimentation cannot avoid some awareness of how their product looks nutritionally as compared to alternatives when that information is required to be present on the label. This increased nutritional awareness on the part of both consumers and manufacturers is likely to have a salutary affect on the American diet.

Another long-term effect one can anticipate is an accumulative increase in consumer knowledge of nutritional subject matter. Required disclosure and required standardization of nutritional claims puts the stream of nutritional information in a recognizable frame of reference which can be learned by consumers. In addition, the new service enables consumers to use nutritional information as a meal planning device. Consumers can have a new level of confidence in manufacturers by virtue of more knowledge about complex product characteristics.

The nutritional labeling initiative as public policy aimed at consumer protection is likely to have much more far-reaching effects than the Fair Packaging and Labeling Act. While it is too early to know whether these effects will materialize, it is apparent that at least a policy evolved that could be implemented. It is also apparent that the matter of nutritional labeling is a very complex and multidisciplinary topic. How were the principles involved translated into rules which could be woven into the complex fabric of a sophisticated industry? How did this policy emerge?

The Nutritional Labeling policy emerged from within the Food and Drug Administration. This agency is somewhat multidisciplinary in character being comprised of people with expertise in nutrition, food science, medicine, and a few others. But in addition, it contains many people with practical industry experience. It was fashionable a few years ago to decry the infiltration of what was intended to be a regulatory agency by industry people. While I'm not sure that this is the best way, it seems very likely to me that this industry experience was most useful in the evaluation and promulgation of rules that would work. Although some of the multidisciplinary characteristics of the Food and Drug Administration may have been unplanned (the input of industry knowledge through infiltration), it turned out to have sufficiently broad based intelligence to develop a realistic policy. The integration of pure principles into the operational nitty-gritty was achieved. This integration was never achieved in the packaging policy experience.

The next chapter in the nutritional information story involves advertising content policy proposed by the Federal Trade Commission. The momentum came from the groundwork done on nutritional labeling within the Food and Drug Administration; in fact, a key person was transferred between those agencies. It is not clear what the future of this advertising content policy will be. It is my judgment that the Federal Trade Commission just does not have the intellectual resources to make

definitions, formulate policy, and enforce it. The Federal Trade Commission is almost entirely composed of legal people. While they may work effectively in the quantitative dimensions of market performance, they have no multidisciplinary base upon which to draw for developing, promulgating, or enforcing policy in any qualitative area.

Assessment of Current Programs

It is interesting to look at programs of current interest under the topic of consumer protection. Possibly the unit pricing, open code dating, and nutritional labeling are the more important current examples (Lenahan et al.; McCullough and Padberg; U.S. Department of Agriculture). I think the consumers' interests have primarily been aroused because of the confusion in the market place resulting from the process of experimentation in product quality. When we had only a few staple commodities and little packaging, these programs had no meaning. They relate primarily to a processed food industry where work is taken out of the kitchen and incorporated into the characteristics of the product. Since we have no conceptualization of objectives in qualitative competition, we have tended to draw upon quantitative objectives in design and rationalizing of these programs.

While advocates promote them as a specific market information aid, consumers tend to see them as an element of general security in a confusing situation. Inasmuch as consumers like them there will probably be political support for the implementation of these measures and perhaps others. There seems to be some indication that nutritional labeling may have a more far-reaching and profound influence on the food industry than unit pricing or open code dating. Even at best however, these measures are piecemeal and incomplete. It is not clear to me that they respond to the most crucial and important effects upon consumers of the tremendous resources we are pouring into product experimentation.

Summary and Conclusions

The food industry is very large; it contains many firms and is generally competitive in character. Two major power blocs exist in the food industry structure—the oligopoly core of food distributors (food chains) and the oligopoly core of food manufacturers. Our experience with the large food chain represents about three-quarters of the century. While it was baffling at first, we have come to understand its organization and behavior. It seems to be unique among oligopoly structures in that it has a major focus of competitive activity involving private label products which are price-competitive. Although nonprice competition may also be undertaken by these large organizations, their major thrust in price-competitive activity tends to lend a useful character to their overall performance.

Since World War II and since television, the food manufacturer has become a very large and conglomerate power bloc. The competitive impetus within this power bloc is directed to new product development and introduction. This process of experimentation is very different than the Marshallian type of economic activity. Its effects on society, both good and bad, are different in character and we just don't understand them. It seems likely that the emergence of some sort of public technostructure is necessary to identify the public well-being and set up instrumentalities for maintaining surveillance and guidance of this Galbraithian type of economic activity.

As I have watched the struggle in Congress over the proposed Consumer Protection Agency, I wish I could be more enthusiastic about the kind of agency that is proposed. It is my judgment that the emergence of a consumer advocate in government is more explainable in the stream of ineffective history of the consumer movement than it is in relation to potentials or needs. I urge the creation of a multidisciplinary public technostructure which would become the institutional base for the consumer movement. It would consolidate the knowledge and expertise needed to identify the public interest in both qualitative and quantitative aspects of microeconomic performance in consumer goods as well as set up machinery for guiding these industries.

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Public Policy Changes Needed to Cope with Changing Structure

Dale C. Dahl

Public policy dealing with the organization and operation of the U.S. food system has been the subject of numerous articles issued through this Association. And with modest exception, the focus of these efforts has been the agricultural price and income policies directed to the resolution of important farm welfare problems. Historically, less direct analytical attention appears to have been paid to the welfare of food and fiber consumers and the equity problems of the numerous firms and agencies that supply farmers with their inputs or assemble, store, transport, process, and distribute farm products and items made from them.

There are several "categories" of legislation and regulatory rules that bear upon the structure of the food and fiber system. These policy categories include (*a*) agricultural price and income policies, (*b*) consumer protection policies, (*c*) antitrust policy, (*d*) market regulations, (*e*) taxation and business association policies, (*f*) land and ecological policies, and (*g*) farm labor policies. (These policies can be grouped in various ways. See Dahl.)

The purpose of this paper is to briefly consider the structural consequences of each of these policies in more recent years, to review the nature of structural change at several industrial levels in the food and fiber system and its performance results and, finally, to propose the study of changes in public policy that might cope with this changing structure.

Structural Implications of Current Public Policy

Each of the several policies directed at the U.S. food and fiber system has structural implications, i.e., the accomplishment of policy goals encourages particular organizational configurations in terms of numbers, sizes, and location of plant and business firm entities and the nature of the products and services produced. Each of the major policies will be examined in terms of their structural implications.

Agricultural Price and Income Policies

Historically, the price and income policies for agriculture in the United States have been directed at the resolution of two important economic welfare problems. The first problem is that of price and income instability brought about by the existence of severely inelastic aggregate demand and supply relationships for food in the United States along with a lack of farm bargaining organization and the vagaries of weather. Left uncontrolled, agricultural prices would fluctuate severely from one year to the next, depending mostly upon supply factors beyond the control of the individual farmer. An important part of U.S. agricultural policy was to help reduce severe fluctuations in agricultural prices and income for the welfare benefit of the farmers in this country. Houck also pointed out that severe price fluctuations also serve as poor allocative indicators within agriculture and between agriculture and the remainder of the economy.

The second major concern of U.S. agricultural policy has been to bolster sagging farm prices which diminish gradually over a substantial period of time mainly due to the technological "treadmill" and the behavioral limitations imposed on farmers by the market structure characteristics that make them "price takers" in both product and input markets. Thus, price support, demand expansion, and supply management programs of the federal government also have been directed to the resolutions of low income problems, at least up to more recent times.

When foreign markets for agricultural products expanded rapidly in the early 1960s, it

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became clear that agricultural prices would not require continued support at levels beyond the market clearing price that would have been established in absence of price supports. Accordingly, price floors were established with the 1964 Agricultural Act that gave a new focus to agricultural policy during the past decade. While there has been some protective security, in large measure farmers have been left on their own to produce as much as they could within the limits of acreage allotment programs increasingly eased in more recent years. It has been noted that the new legislation has not been directed to the price instability problem.

It should be noted at this point that agricultural policies dealing with farm income bolstering and price instability did not directly deal with farm numbers, sizes, and farm location except in an indirect sense. Due to the fact that approximately two-thirds of all farms could not be meaningfully helped by price and income policies, the implicit policy of the federal government was to discourage small farms and to encourage large farm operations. Any review of historical statistics regarding farm numbers and sizes will demonstrate that farm numbers by size category have been increasing for very large farms and decreasing substantially for the smaller farms.

Thus, the structural consequences of both the economic forces at work and the agricultural price and income policies up to 1964 were to encourage an increased concentration within the farming industry itself. This increase in concentration has not gone unabated with the 1964 change in legislation.

More recently farm numbers have leveled off, encouraging some students of agriculture to suggest that the farm number decline has stopped and that we may not see substantial changes in farm numbers in the years ahead. I disagree with this conclusion, arguing that the high farm prices that have been enjoyed during the last several years have encouraged relatively inefficient farms to stay in agriculture. As soon as farm prices begin to decline again, we will see a decrease in farm numbers start afresh.

There are structural implications for other dimensions of the U.S. food system arising out of the changed agricultural price and income policy initiated in 1964. Given the fact that farm price floors were established, thus allowing substantial fluctuations in farm prices, a rejuvenation of the futures markets has come about. These markets have operated to protect farmers and agribusiness firms from losses as well as to provide a mechanism for allocating products throughout storage periods. Another important dimension of structural change has been an increase in firm numbers and business volume for agricultural export activities. Substantially increased demand for U.S. products by countries through the world has expanded firm numbers and made many export companies multinational in character.

Consumer Protection Policies

Policies focused at the welfare of the U.S. food and fiber consumer are multiagency in scope. At the federal level, policies relating to consumer income are part of both the Department of Health, Education, and Welfare and the Department of Agriculture; policies relating to the protection of consumers from health hazards associated with individual products are provided by the Food and Drug Administration; and protection for the consumer related to misleading information is provided by the Federal Trade Commission. Many such agencies exist at state levels as well.

Most of these policies are mute with respect to the structure of the U.S. food and fiber system and have been adopted within the framework of that system. It might be argued that a substantial public technostructure has developed in relation to these policies, but their impact upon the number and size of food retailers and manufacturers could not be firmly argued except to suggest that the increased cost that might be imposed upon food manufacturers and distributors as a result of changing regulations can be borne only by larger business entities. However, such an argument may be spurious since it is doubtful that any food manufacturer has been identified whose business failure can be associated with substantial government regulation.

Antitrust Policies

The antitrust policies of the United States are also multiagency in terms of enforcement. In addition to the Antitrust Division of the Department of Justice, the Federal Trade Commission and the U.S. Department of Agriculture play important roles in defining and enforcing the antitrust policy relevant to the U.S. food and fiber system.

The major concern of the antitrust enforcement bodies and the courts has been the anticompetitive conduct that can result from concentrated market structures rather than the structural developments themselves. The notable exception to this philosophical tendency has been with merger policies.

The structure of food retailing, manufacturing, and input manufacturing has continued to be marked by the single word "concentration" without regard to the antitrust policies themselves. Antitrust policies do not in and of themselves tend to encourage certain structural forms within industries but rather tend to discourage extremely concentrated activities to the extent that they do result in anticompetitive conduct. The major proposal by Senator Hart, not yet adopted but in discussion, would change the focus of antitrust activities to encourage structural change rather than to merely look at anticompetitive practices themselves.

The cooperative exemption from the antitrust laws has received attention in recent years, given the major organizational developments (and the subsequent market conduct) of highly concentrated agricultural cooperatives, particularly in milk and fertilizer.

The two industries of milk and fertilizer stand in bold contrast in terms of the results of their conduct. Allegations have been made as to anticompetitive conduct by major agricultural milk bargaining associations in the Midwest particularly as they relate to Watergate. Some of these allegations are presently before the courts in Kansas City and the results will have a great deal to say regarding the extent to which agricultural cooperatives are exempt from the antitrust laws, a matter of continued concern and speculation by students of agriculture.

An interesting structural result has come about as a result of the extensive expansion of agricultural cooperative fertilizer manufacturing and distribution in the United States in recent years. At the present time, approximately 40% of the fertilizer sold to farmers is handled by a single agricultural cooperative (Central Farmers, Chicago) and its regional agricultural farm supply cooperative members. Within the last two years, this cooperative has sold its fertilizer to farmer members at prices considerably below world market prices and has served as a low price leader of private firms in the fertilizer manufacturing sector.

The net impact of the agricultural cooperative exemption has been to encourage concentration in agricultural markets by cooperatives. This is evidenced by the decreasing number of local and regional cooperatives in the United States and increases in their size and scope of influence.

The net result of the antitrust policies in the United States has been to not discourage increased concentration and to encourage vertical and conglomerate integration in farm supply agricultural and food markets.

Market Regulation

A large number of individual pieces of legislation at federal and state levels regulate market transactions or license individual firms that operate in farm supply or farm product markets. The apparent impact of these laws is to discourage entry or to encourage the exit of those firms which do not meet basic technical qualifications or financial conditions or which have engaged in various anticompetitive practices in previous marketing activity.

While it might be argued that such policies are healthy and are not severely restrictive, it should be noted that the continuing morass of legislation at a variety of levels has made it increasingly difficult for firms to determine where and to whom they may market their product and what standards have to be met. This tends to increase the cost of business operations and may be burdensome for the small firm.

While the net effect of market regulation may be to modestly and appropriately withhold firms from entering industries for good economic and social reasons, the result is to encourage concentration in markets via this policy purpose.

Taxation and Business Associations

Agricultural taxes by federal, state, and local governments may be grouped into three categories: (*a*) income, (*b*) real and personal property, and (*c*) estate taxes on intergeneration transfer. Farmers historically have received special treatment both with respect to themselves as individuals and as they organize into agricultural cooperatives.

In general, farmers' income positions have

encouraged the federal government to allow farmers to take special credits for land improvements and to encourage enterprise development by giving special tax exemptions for a variety of types. Property tax treatment has similarly favored farmers, but estate taxes at both federal and state levels generally have not given special favor to the farming community.

The effect of favored tax treatment, of course, is to encourage nonfarm interests to engage in agricultural activities so as to take advantage of any tax privileges granted this particular industry. The result has been an increased number of "tax-loss" business entities formed as cattle operations, land holding companies, and so forth. Because most of these entities are formed using sophisticated legal business organization structures, such as corporations or limited partnerships, increased state legislation has developed to prohibit or severely limit the activities of farm corporations and limited partnerships from engaging in agricultural activities and/or taking advantage of the tax laws written primarily for the benefit of bonafide farm operators.

The effects of this legislation have also been concentration increasing. The "nonfarm-business interests" farm organization is concentration increasing because it is usually necessary to buy out smaller operations to carry forth the objectives of the tax-evading farm operation.

Land and Ecology

Most of the land and ecology policies in recent years have dealt with land use problems at the interface between urban and rural areas or have dealt with pollution control problems that relate to agricultural production activity.

Land use regulations have been mainly concerned with the problem of accommodating urban development at the expense of agricultural production. Agricultural land has largely been treated as a vast resource that is continuously available for urban expansion projects of all types. This philosophy has had an expansionary effect in the nonfarm, urban, residential, and business area but reversely has had a concentration-increasing impact on agriculture by virtue of the fact that it draws farms and farmland out of agricultural production.

Ecological problems associated with agricultural production and food processing have been resolved largely by imposing abatement procedures at the expense of farms or food and fiber processing firms. The proposed effect is to keep the environment rid of various types of impurities. Given that these increases in agricultural production costs are not met with higher farm prices or higher prices at the markets in which food processors participate, it would result in fewer smaller or inefficient firms at the food and farm production levels.

On balance, land and ecological policies appear to have largely a concentration-increasing impact throughout the food and fiber system.

Farm Labor Policies

There has been a substantial increase in legislation arising out of the concern for farm laborers in terms of wages and working conditions. In addition to serving as a basis for increased numbers of labor organizations operating in the agricultural community, this increased legislation has also provided and created a substantial increase in labor and fringe benefit costs that have to be incorporated into agricultural production costs overall. Due to the fixed character of some of these costs, the larger firm benefits more than the smaller in taking advantage of efficiencies gained with larger numbers of farm workers. Although slight, the result is to give some encouragement to larger firms. The effect of this policy is concentration increasing.

Conclusion

Perhaps not surprising, a review of the several policies that relate to the U.S. food and fiber system suggests that the policies either do not deal directly with structure in terms of the number, size, and locations of plants and firms, or where so, they have a generally concentration-increasing impact. The conclusion to be reached then is this: not only the economic forces that are at work in the U.S. food and fiber system tend to encourage increased concentration, but the public policies that are directed to the solution of various income, equity, and growth problems also have the effect of increasing the concentration of firms at each level of the farm supply, ag-

ricultural production, and food processing and distribution system.

Structural Change and Economic Performance

The structural changes in the U.S. food and fiber system may be recounted horizontally at different levels of the production marketing system.

The structure and conditions evaluated usually include (*a*) the number and size of firms, (*b*) the nature of the product, and (*c*) the ease of entry and exit. The status and changing pattern of these structural characteristics permit testing of hypotheses regarding market conduct, the broad dimensions of which can be deduced from economic theory. The results of this conduct, characterized in terms of several performance dimensions, provide the basis for suggesting whether changes in performance are desirable and hence whether structure and conduct alterations are in order.

For the sake of convenience, the U.S. food and fiber system may be viewed as consisting of three major segments: (*a*) the farm input industries, (*b*) the farming sector, and (*c*) the food processing and distribution sector.

The Farm Input Industries

The changing nature of the input markets in the United States have been characterized by Minden as follows:

> Each of the input markets can be characterized as having (1) decentralized its manufacturing operations to locate closer to raw material sources and users; (2) integrated manufacturing and distribution in an attempt to exploit supposed economies of size at the local outlet; (3) undertake a rather aggressive program of merchandising their products as part of a service-product package; (4) becoming increasingly systems conscious; and (5) continued product diversification via development of products that complement traditional product lines in various types of mergers, acquisitions, and joint ventures. (P. 678)

In general, the manufacturing of farm inputs has become increasingly concentrated with fewer larger firms engaged in input production processes and located at areas of some considerable distance from the farmer customer. As indicated by Minden, manufacturers of farm inputs have attempted to expand their product lines and to differentiate their product to the extent possible. There is considerable restriction of entry, largely on economic grounds, in these manufacturing activities.

The conclusion is that farm input manufacturing is represented by a series of oligopolies possessing considerable market power which arises from their size and their ability to distinguish their product through advertising and product change.

Increasingly, manufacturers have integrated forward to include at least the wholesaling of the farm inputs they manufacture and in some cases to the retailing of farm inputs as well. Where input retailing has been impossible or thwarted by existing firms, elaborate franchising and integrating efforts have been made to encourage the distribution of increased volume of inputs used in agricultural production through the United States.

In general, the number and size of wholesalers and retailers of farm inputs have been changing in accord with the number and size of farm firms located throughout the United States. Farm numbers, of course, have been decreasing as their size has been increasing. Input distributors have become increasingly service conscious, recognizing that farmers are interested in buying product-service packages, many times asking input suppliers to provide them with the product as well as the services necessary in relationship to it. Examples include soil testing and application along with the fertilizer itself. In general, the farm input distribution system must be regarded as monopolistically competitive and leaning toward becoming a differentiated oligopoly in structure over the longer haul.

The Farming Sector

The structural hallmark of the farming sector of the U.S. economy has been that it is most nearly like the purely competitive model of any industry in existence. This is to say that the farms are sufficiently numerous so that no one farmer has an appreciable influence over market prices through his actions alone, that he is unable to convince buyers that his product possesses unique characteristics different from those of other farmers, and that farming is a relatively easy business to enter and exit. Increasingly, these "traditional" structural characteristics of U.S. farming are being challenged by developments within this sector.

Walter Heid has concluded in a recent study that farm production is less characterized by a

large number of small units or rather is characterized by farms that are larger and more specialized. According to Heid, the most relevant consideration in looking at concentration within the farming sector is the amount of production and land area that is under control of fewer and larger farms. To the extent that farm numbers continue to decrease and a few farms have substantially increased in size, farmers are placed in the position of some degree of market power which previously was unattainable both in their input as well as their product markets.

Through their ability to specialize and organize through cooperatives, farmers also have tried to differentiate their product by region and by other characteristics. Considerable emphasis has been placed in recent years on "check off" legislation, which involves development of advertising and research funds at state levels to encourage consumers to use more of particular farm products and to distinguish the unique characteristics associated with geographic areas.

Most students of agriculture would agree that entry into farming is extremely difficult from an economic point of view. The price of land and buildings is so substantial that it is almost impossible for many young people to get started in farming unless they are in a position to inherit the farm from their parents.

The result of these considerations is that the farming sector is becoming less purely competitive than before and is gaining in market power. However, it must be concluded that despite these relative gains, the number of farms and the nature of product differentiation is still sufficiently like that of pure competition so that farmers are unable to exercise substantial market power in their input and product markets. Farmers still are price takers and, to a considerable degree, they will be in this position for a long time.

The Food Processing and Distribution Sector

Traditional farm product assembly markets have been challenged in more recent years. Increasingly, farm food processors and distributors have relied upon direct contact with farmers or major assemblers for the procurement of their raw material needs. The emergence of direct buying of grain products and the bypassing of country elevators is a recent example, matched by a continued earlier decline in major terminal livestock market receipts registered during the 1960s.

The resulting conclusion is that farm product assembly increasingly has been assumed either by the farm producer through his agricultural cooperative or by the processor as part of vertical integration activities back through the assembly system. The result of these developments is to increase the concentration in farm product assembly markets such that these markets can be thought of as being more oligopolistic in structure than ever before.

Food processing must still be regarded as a mixture of atomistic competition and oligopoly. Greig has characterized the food processing industry as consisting of the competitive component and oligopoly component, while others regard it as a system of oligopoly with a competitive fringe. This distinction has been emphasized by Forrest Walters in the paper presented earlier in this session. Both Walters and Padberg have noted that the food retailing industry tends to be oligopolistic in structure. Their reasons have been developed elsewhere.

In a recent study of the food service industry, Richard Johnston has concluded that this segment of the food and fiber system has become increasingly concentrated and has become more like a differentiated oligopoly. The development of large institutional food users and food restaurant chains leads Johnston to this conclusion.

To complete the structural picture forces us to conclude that individual consumers and household entities have largely operated as individual buyers and have, in accord with their atomistic structure, acted as price takers in a manner similar to that exhibited by U.S. farmers.

Conclusion

The overall conclusion is clear. Producers and consumers possess little economic power in the market place and are increasingly at the disposal of oligopolistic structural forces that tend to characterize the larger segments of the U.S. food and fiber system. The ability of input and food firms to manipulate or adjust prices at will and with limited contest has been clearly demonstrated during this period of heavy price inflation through the U.S. economy. To the extent that competition is nonprice, firms are encouraged to increasingly

emphasize the importance of trivial or nonexistent product or service elements associated with the products that farmers or consumers purchase.

In the face of this situation and tendency for change, there are four categories of public policy that should be changed in the near future.

Public Policy Changes Needed

I recommend that four categories of public policy be addressed in the near future to insure consumer protection, to discourage undue concentration of economic power, to minimize business red tape, and to insure a complete economic policy for the United States both domestically and internationally.

Producer and Consumer Protection

As economists, we promote rational economic decision making by consumers and producers. Therefore, it is reasonable for us to promote policies that provide the greatest amount of information basic to rational decision making.

Economic decisions must be based on technical as well as price considerations. It is important that individuals who make purchasing decisions be knowledgeable about the significant technical dimensions of the products they buy. The technical knowledge needed is that which has a profound influence on how the products they purchase are intended to be used in production or consumption activities. Additionally, individuals, producers and consumers, should be aware what alternative prices are available for different qualities and quantities of products that they may purchase.

For the agricultural producer it is extremely important that some method be devised to assure the farmer that he can properly appraise the technical qualities of the inputs that he is purchasing. Mather and I state:

> On the product side of agriculture farm prices at markets are regularly reported by the Market News Service of the U.S. Department of Agriculture. These reports serve as the basis for informed marketing decisions by farmers and are also useful to negotiations and planning in the industries involved. We suggest that this federal agency expand its services to include the major farm imputs.
>
> Such a suggestion, however, hinges upon the development of meaningful grades or standards for farm inputs. Obviously you cannot report a price for farm tractors unless the product is highly specified in terms of its size, equipment, and so forth. But defining input product standards does not seem to be insurmountable. The input industries themselves can determine the "representative" product to be priced. Thus we recommend grades and standards be developed for farm inputs for price reporting purposes. Such an effort will also encourage technical competence in inputs by farmers.

I would argue that we should go further than that with respect to food and fiber products at the consumer end of the system. I argue that consumers should be given the advantage of a technical evaluation of all of the food products that they buy. If there are different qualities of the product that are being sold, these qualities should be identified according to some comprehensible standard of reference and this information should be posted clearly in retail stores. In addition, it does not seem unreasonable to me to require that products be packaged in standard sizes according to weight or volume. Thus, package prices could be compared directly rather than forcing unit price manipulations via slide rule or fine print. It is imperative that we provide the consumer an opportunity to make price-quality decisions on the spot and in accord with his tastes and preferences. To carry forth such "extreme" measures and provide the consumer with a voice in his decision-making processes, I support the consumer agency recommended by Padberg.

Also for producer and consumer protection, I suggest we continue to provide minimum consumer income maintenance in the form of food stamp programs and continue to develop other income maintenance programs that would help divide the farm problem into its proper dual components, one of supporting the income of commercial farmers and providing poverty welfare payments to those farmers who could not achieve parity income levels regardless of the price programs initiated. To minimize price instability and farm welfare and allocative efficiencies, I would encourage the federal government to maintain a system of stocks which would tend to level out prices of farm commodities over time and which could be used in economic policy in the international sphere as appropriate to our foreign policy needs and domestic requirements.

Antitrust Studies and Monitoring

I would support Senator Hart's Industrial Organization Act which provides for a continued monitoring of the structural changes taking

place in our economy so as to identify industries and firms which have the potential for violation of the antitrust laws as they are presently written. Rather than waiting for firms to structurally be in the position to violate the antitrust laws and then responding to such violations, it seems to make much more sense to me to try to identify tendencies in structure that lead to violations of the antitrust laws and to discourage structures that have strong tendencies. Such studies are now exemplified by some of those conducted by the Federal Trade Commission and may be helpful in terms of identifying optimum structural configurations for different industries in light of the performance results that are considered appropriate and consistent with our antitrust goals.

These monitorings should also include a continual study of organizational structures of agricultural cooperatives. Agricultural cooperatives should be exempted from the antitrust laws only to the extent that they can, through their new organizational structures, provide positive performance results in markets where solutions to anticompetitive activities are difficult to achieve.

Uniform Regulatory Laws

Regulatory laws involving agricultural inputs or agricultural products at all levels of legislative authority that attempt to license or restrict the way in which products should be moved within states and throughout the United States should be studied for uniformity.

Considerable efforts need to be made to reduce the number of laws and conflicts that result in such a wide range of legislation, much of which goes unenforced. It is recommended that a comprehensive review of agricultural regulatory laws be undertaken with the aim of minimizing their duplication and inconsistencies at the earliest possible date.

Comprehensive Policy Planning

It is increasingly evident that it is impossible to carry out any agricultural policy without having a substantial influence on a wide range of other economic policies throughout our food and fiber system and vice versa. Therefore, it is recommended that a comprehensive policy unit be developed in the federal government that considers a total food and fiber policy and that all of the ramifications of this policy be judged together rather than as separate piecemeal activities. A systems approach to U.S. food and fiber policy is long overdue and must be incorporated into our planning activities in the future.

Conclusion

We are confronted with the fact that we have been unable to comprehensively articulate the performance results we desire from the economic system we have inherited. We must conclude that we have encouraged, even if by default, a continued increase in economic concentration and a subsequent vesting of the power of product and price definition to a decreasing number of decision makers within the food and fiber system.

The time has arrived for those of us that regard our purpose as an attainment of the collective good to spend our energies in providing a normative basis for public policy that deals with the quality, quantity, and price results to consumers as well as the resolution of inequities that result from a discontinuity of economic power throughout the economic sector that focuses upon the production and distribution of food and fiber.

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Discussion

James E. Martin

The authors of the three papers presented at this session are to be commended for (*a*) providing their insights and views of structural changes that have and are occurring in the food industry, (*b*) providing their assessment of the implications of these changes, particularly with respect to their impact on the future conduct and performance of the industry, and (*c*) suggesting alternative public policies which, if implemented, would attempt to improve the efficiency and performance of the industry from the standpoint of the general public welfare and the environment for individual decision makers (especially the consumer) at the various stages between the input sector and the consuming sector.

Each of the authors, I believe, would generally define the food industry as "the complete chain of industries that produces inputs and commodities, processes and markets food, e.g., the farm input, farm producer and food processing, wholesaling and retailing industries" as outlined by Walters. However, Padberg's paper deals almost exclusively with the processing, marketing, and consumer sectors. Obviously, time and space limitations prevented the authors from providing complete coverage and detail with respect to this complex industry in this broad context. The three papers taken together do, however, provide detailed characteristics of various sectors of this important, encompassing industry.

Basically, each author would characterize the input sector and the processing, wholesaling, and marketing sectors of the industry as having an oligopolistic characteristic. Walters argues that the processing sector might be divided into two categories, one category processing homogenous products (commodity processors) which tends to be competitive and a second category processing "package goods" which is oligopolistic. Walters also cites a study by Heid pointing out that the current trend towards fewer and larger farm units may bring into question the use of the purely competitive model in the farm sector for some commodities in selected regions of the country.

Each of the authors also proposes additional antitrust studies, monitoring, and remedial action if such studies identify structures that lead to antitrust violations or inefficiencies in the industry. Both Dahl and Padberg recommend the establishment of a consumer protection agency and Dahl would include producer protection as an additional responsibility of such an agency. Dahl also suggests a review and study of regulatory laws applying to agricultural inputs and products that license or restrict in an attempt to unify these regulations into a set which maintains adequate consumer protection, safety, etc., at minimum cost in each sector of the industry.

Finally, Dahl suggests comprehensive policy planning for the food industry. He states that a systems approach to U.S. food and fiber policy is long overdue. Because of the complexity of the food industry and the numerous agencies, regulatory requirements, etc., which have an impact on the inputs and products in each sector of the industry, I find this suggestion of comprehensive policy planning of critical importance.

It would appear that any comprehensive policy-planning program of the food industry could, should, and would include the various parameters and suggestions contained in each of the three papers presented. Such a policy-planning program might provide Congress as well as decision makers within the industry with more complete information of the likely impact, including the costs and benefits, of changes taking place within and external to the industry. Without such comprehensive policy planning at the national level it will become increasingly difficult for Congress and individual decision makers within the industry to supply adequate, safe food and fiber efficiently and at reasonable costs.

Because such policy planning has not been done, it is now difficult to determine the added costs associated with food and fiber products resulting from regulations imposed by FDA,

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This paper was presented in a session entitled "Structural Changes in the Food Industry: Implications for Future Public Policy."

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ICC, IRS, EPA, the Department of Labor, the Department of Agriculture, and other federal and state agencies. Add to these costs the effects of major cost changes associated with energy in all sectors of the industry and the increased uncertainty associated with this change and we find ourselves in a situation in which consumers are complaining about high food prices and do not know who to blame. Hopefully, if a systems approach was initiated on a comprehensive policy-planning program for the food industry, many of the real problem areas could be identified and actions taken to improve the efficiency of the industry.

While the suggestions included in the three papers presented should become a part of such a planning program, expertise from all disciplines related to the food industry would also have to be included to insure the program's success. If an additional agency were created and charged with this responsibility, it would have to relate and interact very closely with practically all other federal and state agencies.

Discussion

A. C. Hoffman

By the standards of conventional wisdom in the field of industrial structure and performance as laid down by Bain, I thought the papers by Walters, Padberg, and Dahl were quite good. The trouble is that events have broken through the parameters of this conventional wisdom. I refer of course to "stagflation" and the wage-price spiral, which are directly related to industrial organization but which are not treated in any of the papers, and this is my chief criticism of them.

Of the three papers, I thought that of Walters was most relevant to the topic of our meeting as I understand it. He suggests two alternatives to restore and preserve workable competition in the food industries: (*a*) the "sledge hammer" approach to restructuring where needed by some type of antitrust legislation involving numbers of firms and share-of-market or (*b*) a graduated tax on corporate profits above the $50,000 pretax level. Walters favors the second, whereas I would choose some variant of the first. But I will say for Walters that he steps into the ball when he swings.

As Padberg says of his own paper, it follows the conventional wisdom but with some new insights which I found very interesting and with which I generally agree. He correctly points out the basic differences between the national brand companies which emphasize experimentation and innovation for food products and the integrated chains which emphasize price through their private brands. But in my judgment he overdoes this a bit. The food industries are not unique in having these two channels, and he implies somewhat more protection to the public than I would from the competition between them. Padberg is of course right when he says too little attention has been paid to what he calls the qualitative aspects of economic performance, and his suggestion for a multidisciplinary technostructure in a consumer protection agency is a novel one. I wish there were more time to discuss these ideas of Padberg.

Dahl has given us what I think is an excellent resume of the various categories of legislation affecting the structure of the food and fiber industries, many of which have the effect (usually unintentional) of increasing economic size and concentration. With respect to the very important area of antitrust, he rightly believes that the policy thrust should be toward the structure itself rather than on anticompetitive acts and practices with which present legislation is mainly concerned. I am delighted that Dahl has aligned himself with that small but I hope growing band of agricultural economists who would support Senator Hart's Industrial Reorganization Act.

As I said at the outset, my main criticism of these papers is that they do not fully face up to our current economic crisis, so I am going to depart from the papers and address the topic directly.

Conventional wisdom about industrial structures tolerates and even encourages a fundamental misconception, namely, that competition is the natural state of a modern corporate economy. For years economists have taught and written it into their textbooks that, while large enterprises have advantages up to a point, eventually they are overtaken by diseconomies of scale so that the tendency toward monopoly is self-correcting. This is a comforting doctrine, but it is wrong. The tendency is inevitably and inherently toward fewer and larger firms and toward the disappearance of small ones. The problem will not go away; big business itself is powerless to stop it, and only government intervention can. As one who worked for big business for many years and whose emotional ties are with it, I believe such intervention is in the interest not only of the public but of big business itself, for the alternative to viable competition is government controls and in some cases eventual nationalization.

The reasons for this are of course set forth accurately and in detail by Galbraith in *The New Industrial State*. If any proof were

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This paper was presented in a session entitled "Structural Changes in the Food Industry: Implications for Future Public Policy."

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The views expressed here are solely those of the author.

needed that he knows what he is talking about, one has only to look at what has happened to the American economy within the lifetime of many of us in this room. In many key lines of American industry, including some parts of the food field, you can count the number of competing firms on the fingers of one hand—in some, it may take both hands.

Incredibly, not many economists seemed to worry about this. In many areas there remained a small, if diminishing, fringe of lesser firms; the concentration ratios as computed by the Census didn't seem too alarming (although there were some ominous signs if one looked closely); and a poll of economists taken ten years ago probably would have indicated that a substantial majority of them thought the economy in most areas was adequately structured to insure workable competition. The merger movement of the late 1960s shook everybody up for awhile, but it no longer gets much attention even though it still goes on nearly apace. The steady internal growth of large firms generally, both in terms of absolute size and share-of-market, which in the aggregate is more important than the merger movement in altering industrial structure, never did get much attention and still doesn't.

In terms of performance as distinct from structure, an ostrich-like attitude has also prevailed among the orthodox. The textbooks have always taught, correctly, that monopoly leads to a restricting of supply, a raising of prices, and exorbitant profits. More recently, again correctly, they have come to associate oligopoly with large advertising expenditures, research to improve the selling or cosmetic properties of existing products rather than to develop significantly new ones, and technological sluggishness. But there didn't seem to be much urgency in their dialogues—oligopoly may have resulted in some misuse and misallocation of resources, but the economy seemed to be thriving nonetheless.

Then inflation began, fueled increasingly as it went along by the wage-price spiral resulting directly from the monopoly power of organized labor over wages and that of big business to pass its increased costs along to consumers. This is not to deny that much (probably most) of our current inflation is due to our hot and cold wars and the way we have mismanaged our fiscal and monetary affairs. But we are now in the stage where cost-push factors have largely taken over and Keynesian economics no longer has much effect. A small band of economists, among them Galbraith and Mueller, have been telling us over and over that only some type of control over wages, prices, and profits can break the back of the wage-price spiral after it has taken over, and once again events themselves are forcing us to listen.

The present antitrust legislation has failed in the basic sense that it has not prevented what has happened to industrial structure. Galbraith rightly calls it a charade. In the absence of anything better, I suppose we have no alternative at present but to keep pegging away along the old lines, but we should have no illusions that it will have much effect.

As I said earlier, I am pleased that Walters and Dahl declared themselves in their papers today with those of us who favor more positive steps. I myself am of the view that eventually and in certain key areas, we shall have to have legislation which authorizes limits to share-of-market and minimum numbers of competitors to be allowed, as I have stated and described in greater detail on other occasions.

While such legislation would help to preserve workable competition, it does not of itself solve the core problem, namely, unused economic resources resulting from our failure to cure depressions. Several years ago we thought we had a cure in monetary and fiscal policy—it was called the "New Economics." Now we know differently.

If we can finally bring ourselves to the realization that our private enterprise system cannot reasonably be expected to provide full employment, then maybe we can tackle the problem head on, that is, by the government itself entering the economic arena, not on an emergency basis, but as a permanent adjunct to the private enterprise economy.

The list of things to be done is endless, and I'm not thinking of leaf-raking projects of the kind usually thought of as public service employment. We could start renovating and rebuilding our urban slums where most of the hard-core unemployment exists. We could use the Army Corps of Engineers to lay sewage systems in small towns and rural areas instead of building more dams. Back in the 1930s the government used the unemployed to man warehouses and distribution depots for getting surplus foods to the needy until this system was replaced by the more expensive Food Stamp Plan. Senator Adlai Stevenson suggests the government enter the energy field—if

we can spend $50 billion to go to the moon, maybe the government could launch a project to draw energy from the sun or to extract shale oil or even to drill and refine ordinary oil in competition with Exxon.

I am well aware of the administrative and political difficulties of doing things of this kind and of the storm of opposition it would arouse among those in business, labor, and agriculture who would think their interests were threatened. The ideologists on the right would scream that this is socialism, which by definition it is. But maybe the best of all possible worlds, for the capitalist as well as the socialist society, is an admixture of both.

Our leaders have solemnly told us that our society probably cannot stand double-digit inflation for long, to say nothing of double-digit unemployment which we are now rapidly approaching. President Ford has implored economists to help him with "stagflation," and one can't blame him for feeling a little let down by the profession. It is particularly incumbent on those who profess to be experts on the structure and performance of the economy to come up with something.

Interaction of Energy and Food Prices in Less Developed Countries

C. Peter Timmer

Food is man's energy, but the production of that food requires energy inputs from outside the food system. Indeed, the laws of thermodynamics guarantee that more energy is required from outside the system than will be available in the food itself, and this becomes increasingly significant the more complex the agriculture and the more involved the marketing activities performed on the food after production. It is important to realize, however, that no matter how primitive and subsistence-oriented a food system is, it still requires far greater energy input than ultimately becomes available for human consumption.

Most of this energy input even in highly commercialized agriculture is from the sun and hence is "free." But this should not cause us to lose sight of the fundamental inefficiency involved in converting one form of energy into another. The secret is to find a cheap form to convert into a more expensive one. For agriculture, solar energy is the cheapest of all, but natural gas converted into nitrogen fertilizer or petroleum converted into diesel fuel converted into rotary motion in an internal combustion engine converted into irrigation water might also meet the cheapness criterion.

The criterion is economic, not technological. Whether it makes sense to convert five calories of fuel energy into only a single calorie of food, which is the energy input-output ratio calculated by the Steinharts for U.S. agriculture, depends on the relative price of food to fuel (among other things). This economic triviality has frequently been ignored in some of the more alarmist talk about the relationship between the "energy crisis" and the "food crisis." Reputable technologists are seriously advocating the use of energy input-output ratios as the major factor in choosing agricultural production techniques (Pimentel et al.). Such technological reasoning implicitly invokes an "energy theory of value" and leads inevitably toward labor-intensive, land-extensive agriculture and away from mechanized, irrigated, artificially fertilized agriculture. "For example, in Mexic[an] 'ax and hoe' corn culture . . . a total of 1,144 hours of labor was required to raise a hectare of corn. Other than manpower, the only inputs were the ax, hoe, and seeds. By this method the yield in kcal of corn per input kcal was 10.13. The energy ratio is more than four times the U.S. average of 2.5" (Pimentel et al., p. 6).

Mexican "ax and hoe" agriculture will not solve the "food crisis"; it is part of the problem. Modern, energy-intensive agriculture is the only hope for many of the world's present population and for most of its yet-to-be-born. This conclusion should be softened by a number of provisos. The optimal degree of mechanization will depend on relative labor costs. Changing crop mixes, wider use of green manures, and more efficient use of energy in intensive agriculture are possible. But the central core remains. To produce the food supplies needed for adequate nutrition in rich and poor countries alike, the only hope in the next few decades lies in energy-intensive agriculture.

This conclusion raises both technical and economic issues. First, is the energy available to convert low yield agriculture to high yield agriculture? Revelle estimated the energy that would be required in a modernized, irrigated agriculture, and food processing system in India. He included energy for the construction and operation of flour and sugar mills and cold storage plants but not energy for cooking and food preparation in households. Revelle's calculations show that the food energy obtained would be about twice the mechanical energy utilized, in spite of the large amount of energy used to pump groundwater for irrigation.

> For the present average Indian diet of 2,150 kilocalories per day, 410,000 kilocalories of fossil-fuel

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This and the following four papers comprised a session, "Recent Resource Problems of Less Developed Countries," held jointly with the American Economic Association and chaired by Ronald G. Ridker of Resources for the Future.

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> energy per person would be required each year, equivalent to 55 kilograms of coal, costing at 1974 prices, $2.50. That is about a fourth of the per capita use of fossil-fuel energy in India today. For a future diet of 3,700 kilocalories of primary plant materials and a population of 1.2 billion people, instead of the present 580 million, the total energy requirement for agriculture would be the equivalent of 95 kilograms of coal per person, or a total of 114 million tons per year. Estimated reserves of fossil fuels in India are between 100 and 1,000 tons per person. Hence if India relied on her own fuel reserves, enough energy would be available for a modernized agriculture for several hundred years. (Revelle, pp. 169–70).

Table 1 reproduces Revelle's calculations.

Despite the apparent cushion of Indian fossil fuel supplies relative to the needs of a high yield agriculture, Revelle emphasizes that these provide only short-term promise. Development of the rest of India's economy, commensurate with a modernized agriculture, will also be energy-intensive. Fifty years from now India and most other countries will have to rely mainly on non-fossil-fuel energy sources—probably nuclear and solar—for the great bulk of their energy requirements.

The pressing issue is what happens in the interim. Since the physical resources are available to support high yield agricultures in most parts of the world, the remaining questions about food supplies are economic, social, and political. The rest of this paper attempts to identify some of the longer-run economic relationships between the price of (nonsolar) energy and the price of food that are a consequence of the necessity to develop in the LDCs high yield, fossil-fuel-based agriculture over the next few decades. In turn, the economic relationships have strong social and political implications for developed and developing societies alike.

In the short run, farmers may reasonably assume that the prices of their inputs are fixed and not subject to influence by individual decisions about input and output combinations and levels. Much of the recent work done on the quantitative impact of fuel and fertilizer shortages on food supplies uses this microperspective. But in the long run, the equilibrium price in the food grain market depends on food grain supplies available (among other things). The level of these supplies, both from domestic and international sources, depends at least partially on the use of fuel and fertilizer in the production of the commodity. The interrelationships between demand functions and production functions that determine this longer-run macroequilibrium also have significant implications for the long-run response of farmers to changes in the prices of energy related inputs and for the level of food prices relative to energy prices.

A very simple macromodel can illustrate the points. The model has already been used to examine the relative magnitudes of short-run and long-run demand responses to changes in fertilizer prices (Timmer). The present version is extended to look at energy related inputs

Table 1. Food-Energy Yield versus Mechanical-Energy Use for a Modernized, Irrigated Farming and Food Processing System in India

	Millions of Kilocalories (per hectare)	Millions of Kilocalories (per ton of food grains)	Ratio of Mechanical Energy Used to Food Energy Produced
Irrigation from wells	3.75	0.585	0.167
Chemical fertilizers	3.01	0.469	0.134
High-yielding seeds	0.15	0.023	0.002
Plant protection	0.05	0.008	0.002
Farm tools and machinery	1.05	0.164	0.047
Fuel for machinery	1.97	0.311	0.089
Fuel for drying crops	0.30	0.047	0.013
Transportation	0.18	0.028	0.008
Storage and marketing	0.05	0.008	0.002
Food processing	1.25	0.195	0.056
Totals	11.76	1.838	0.525

Source: Revelle, p. 165.
Note: The table assumes a harvest of 6.4 tons of food grains per hectare, equivalent to the average harvest of corn in Iowa. At present the average Indian farmer produces only about a ton of wheat or rice per hectare. Irrigation and fertilizers together account for about 65% of the energy that would be required directly on the farms to bring about the sixfold increase in yield.

more generally and to examine the input-output price relationships.

The model is built from an aggregate production function and an aggregate consumption function for one of the major food grains:

$$(1) \qquad Q_s = F^{\beta_1} W^{\beta_2} H^{\beta_3} L^{\beta_4},$$

and

$$(2) \qquad Q_d = P_0^{\alpha_1} Y^{\alpha_2} N^{\alpha_3},$$

where Q_s, Q_d = quantity of food grain produced and consumed in a given year, F = fertilizer applications, W = irrigation water pumped, H = area harvested, L = labor inputs, P_o = price of grain, Y = income, N = population, and α_i, β_i = response elasticities of demand and supply with respect to the various factors.

The variables in equations (1) and (2) are scaled to eliminate the intercept terms, and the response elasticities are assumed constant. These two simplifications can be relaxed if desired and further factors added to either function with greater realism but no additional insight gained.

Since our primary interest is in the energy related variables F and W and in grain price, the model can be further simplified:

$$(3) \qquad Q_s = A_s E^{\gamma},$$

and

$$(4) \qquad Q_d = A_d P_o^{\alpha},$$

where $A_d = Y^{\alpha_2} N^{\alpha_3}$; $A_s = H^{\beta_3} L^{\beta_4}$; $E = F\ W$; $\alpha = \alpha_1$; and $\gamma = \beta_1 + \beta_2$ when F and W change proportionately, β_1 when W is constant and β_2 when F is constant.

Combining fertilizer and pumped irrigation water into a single "energy" input allows us to focus specifically on the relationship between energy and food. As Revelle noted, these two inputs would account for almost two-thirds of the on-farm energy use in a modernized Indian agriculture. Even if the two separate factors do not change proportionately, some value of γ will capture their overall contribution to output. Although later it will be desirable to consider fuel and fertilizer separately, for the purpose immediately at hand they can more easily be treated as a single energy input into food grain production.

In the short run when farmers treat the price of grain, P_o, and the price of energy, P_e, as given, the assumption of profit maximization applied to the production function yields a short-run demand function for energy inputs and hence a short-run supply function for food grains:

$$(5) \qquad E^*_{sr} = A_s \gamma^{\gamma-1} P_e^{\frac{1}{\gamma-1}} P_o^{\frac{1}{1-\gamma}},$$

and

$$(6) \qquad Q^*_{s,sr} = A_s \gamma^{\frac{2\gamma-1}{\gamma}} P_e^{\frac{\gamma}{\gamma-1}} P_o^{\frac{\gamma}{1-\gamma}},$$

where E^*_{sr} = short-run equilibrium level of energy inputs into food grain production, assuming profit maximization, and $Q^*_{s,sr}$ = short-run equilibrium level of supplies.

The equilibrium price level of the food grain can be determined by setting the demand and supply functions equal and solving for P_o:

$$(7) \qquad A_d P_o^{\alpha} = A_s E^{\gamma},$$

and

$$(8) \qquad P_o = A_s^{\frac{1}{\alpha}} A_d^{\alpha} E^{\frac{\gamma}{\alpha}}.$$

The equilibrium value of P_o in equation (8) can now be inserted in equations (5) and (6) to find the long-run equilibrium value of energy use and food supplies as a function of energy prices:

(9)
$$E^*_{1r} = \gamma^{\frac{-\alpha}{\gamma + \alpha(1-\gamma)}} A_s^{\frac{1-\alpha}{\gamma+\alpha(\gamma-1)}} A_d^{\gamma + \alpha(\gamma - 1)} P_e^{\frac{\alpha}{\gamma+\alpha(\gamma-1)}},$$

and

(10)
$$Q^*_{s,1r} = \gamma^{\frac{-\alpha\gamma}{\gamma + \alpha(1-\gamma)}} A_s^{\frac{2\gamma-\alpha}{\gamma+\alpha(\gamma-1)}} A_d^{\gamma 2 + \alpha\gamma(\gamma - 1)} P_e^{\frac{\alpha\gamma}{\gamma+\alpha(\gamma-1)}},$$

where E^*_{1r} = long-run equilibrium level of energy inputs into food grain production, and $Q^*_{s,1r}$ = long-run equilibrium level of food supplies.

A comparison of the short-run response elasticities to energy price changes seen in equations (5) and (6) with the long-run response elasticities in equations (9) and (10) reveals striking differences. The short-run elasticity of energy demand by farmers when the price of energy changes is $\frac{1}{\gamma - 1}$; the associated short-run food supply response is $\frac{\gamma}{\gamma - 1}$. If $\gamma = 0.25$ (see Timmer and Falcon for empirical evidence), then the short-run energy demand and food grain sup-

ply elasticities are −1.33 and 0.33 respectively.

The comparable long-run equilibrium responses are $\frac{\alpha}{\gamma + \alpha(\gamma - 1)}$ and $\frac{\alpha\gamma}{\gamma + \alpha(\gamma - 1)}$. The degree of price response from the demand function now becomes an important parameter in determining the long-run response of energy inputs and resulting food grain supply to energy price changes. With the same value of γ as above and α equaling −0.2, the long-run elasticities become −0.5 and 0.125. That is, the long-run response to an energy price change is less than half the response expected in the short run because of the macroequilibrium interrelationships between prices and output.

The interpretation of these results is straightforward. In the short run, farmers regard the prices of output and inputs as fixed with respect to their own decisions. An exogenous change in energy prices will lead to a fairly sizable change in energy inputs, assuming the output price is constant. But this assumption breaks down when the changed output reaches the food grain market and inelastic demands change food prices significantly in the face of relatively small changes in supply. The changed food prices in turn present a new price environment to farmers who will make a new decision with respect to energy inputs, again assuming the price of energy is given exogenously. The model then predicts a long-run equilibrium relationship between energy prices and food prices, assuming that energy prices are set independently of food prices:

(11)
$$P^*_o = \gamma^{\frac{-\gamma}{\gamma + \alpha(1 - \gamma)}} A_s^{\frac{2\gamma - \alpha}{\alpha\gamma - \alpha^2(\gamma - 1)}} A_d^{\frac{\gamma^2 + \alpha\gamma(\gamma - 1) - 1}{\alpha}} P_e^{\frac{\gamma}{\gamma + \alpha(\gamma - 1)}},$$

where P^*_o = the long-run equilibrium price of food grain.

In the short run, no necessary relationship exists between P_o and P_e because in microperspective, food grain and energy enter separate markets with independent clearing operations. But in the long run, equation (11) indicates there is a functional relationship between P_o and P_e, with the elasticity of response of P_o to changes in P_e equal to $\frac{\gamma}{\gamma + \alpha(\gamma - 1)}$. Using the same values of α and γ as before, −0.2 and 0.25 respectively, this response elasticity has a value of 0.625.

Table 2. Value of the Response Elasticity for Long-Run Food Prices When Energy Prices Change: $\frac{\gamma}{\gamma + \alpha(\gamma - 1)}$

Value of γ	Value of α: 0.0	−0.1	−0.5	−1.0
0.0	0	0	0	0
0.1	1.0	0.526	0.182	0.1
0.3	1.0	0.811	0.462	0.3
0.5	1.0	0.909	0.667	0.5
0.7	1.0	0.959	0.823	0.7
1.0	1.0	1.000	1.000	1.0

Table 2 shows some sample values for other possible combinations of α and γ.

Before softening the rather stark results of this simple model with increasing doses of realism, some of the basic lessons it contains should be considered. Table 2 shows the obvious boundary conditions on the value of the food-energy price response elasticity. If production of food grains does not depend on energy ($\gamma = 0$), then the elasticity is zero. If changes in energy use in food production are fully associated with changes in food production ($\gamma = 1$), then the elasticity of food grain price change when energy prices change is one, no matter what the value of α. In this situation any change in energy prices will be fully transmitted to food prices when long-run equilibrium is reached.

A similar conclusion emerges if demand for food grains is completely inelastic. This assumption is frequently built by default into projection models for fertilizer demand. Projecting food requirements on the basis of existing (or recommended) nutritional standards coupled with population and income growth is equivalent to assuming a zero price elasticity of demand. Such projected food requirements are frequently linked to some fertilizer-grain input-output ratio (usually between 1 to 6 and 1 to 10) to determine required fertilizer supplies. Table 2 shows clearly the long-run implications of this assumption; any change in energy prices will be reflected in an identical (proportional) change in food prices.

The interior figures in table 2 are more interesting. All of the nonboundary values are greater than zero and less than one, indicating a varying and not complete transmittal of energy price changes to food prices. Given probable values for γ and α, between 3% and

8% of a 10% change in energy prices is likely to show up ultimately in food price increases. Although one hardly expects such a simple model to explain accurately food price changes after energy prices increased severalfold, a significant part of the world's recent food price inflation ought to be viewed as an approach to a new equilibrium relative to energy prices.

The simple results in table 2 can also be used to examine the impact of an energy pricing policy proposed by some OPEC nations; the price of crude oil would increase (or decrease) in full proportion to food grain price increases (or decreases). Would this be stable or unstable? Table 2 indicates that this pricing policy would be unstable on the boundaries, as food prices would chase energy prices in a continuous upward spiral. But for any of the (more likely) interior values, such a pricing policy would ultimately lead to a new equilibrium since food prices would not fully keep step with energy prices. Unfortunately, for the most probable values of α and γ the convergence would take considerable time and would involve significant reductions in food grain consumption. Growing population and incomes would push the convergence even further into the future, although this energy pricing policy, if effectively carried out, would have strong negative repercussions on any possible income growth except for energy exporting nations.

Thus the model has direct relevance to the present energy-food situation. The feedback effect of low consumer response to changes in food grain prices to equilibrium prices for these foods and hence to profitability conditions with respect to the use of high yield-producing energy inputs into food grain production is too powerful to ignore. Even this simple model captures the essence of the message, which is that energy inputs must be profitable to use. If they are not, then relative food-energy prices must change until profitability is restored.

The focus so far has been on the energy-food relationships in long-run equilibrium. Even without being reminded of Keynes' dictum about the long run, it would be necessary to consider some of the short-run dynamics implicit in the model. Also, the effect of the other variables influencing supply and demand (assumed constant in A_d and A_s) should be examined.

Most energy applications in the food growing process, primarily in fertilizer and pumped irrigation water, are made prior to the time of harvest and sale. When energy prices go up, applications go down, and the resulting diminished harvest does not have an upward effect on food grain prices until several months later. The system is recursive. Since few farmers plan their input use with full knowledge and understanding of the recursive nature of the production-price formation system, several periods will be needed before a new equilibrium can be reached after an exogenous energy price change disturbs an old equilibrium. Indeed, given the significant lag on the energy supply side with respect to price (primarily for fertilizers, but at least the search for oil is price responsive as well) and the great desirability of a positive energy supply response to assure that convergence occurs mostly through greater food output when food prices rise rather than reduced food consumption, the short run may last as long as five to eight years. This gives sufficient time for the fertilizer industry to put in place new investments in the face of a new price environment.

Different short-run supply responses for fuel and fertilizer should also be mentioned here. Although total world fuel supplies may no longer be significantly price responsive in the short run, supplies available for agricultural use probably are price responsive. This implies an ability of agriculture to bid away supplies from other sectors, an ability that will come only through better relative prices for agricultural products. This, of course, is part of what the simple macromodel is saying.

Supply response for fertilizer is a considerably more complex issue. The fertilizer industry has been through several cycles of boom and bust, and as Allen points out, there is a real danger that governments, corporate executives, and industry analysts will now seriously underestimate the future demand for plant nutrients because of past experience with overexpansion. Some dampening of the investment fervor seen in the 1966–67 boom is no doubt desirable, but underestimating future demand by much will seriously prolong the present short-run disequilibrium and cause widespread hunger.

Part of the conclusion from the macromodel that energy applications "must" be profitable stems from the *ceteris paribus* treatment of non-food-energy variables. Freeing them from this immobility alters the conclusion to some degree. In the demand equation, income and

population growth can only add to upward pressures on food prices, other things being equal. Reintroducing these variables strengthens the conclusion that energy inputs into food production must be profitable because the demand function will be shifting outward.

A contrary effect is felt when other variables in the production function are freed. As the price of food rises to make energy inputs profitable to apply, more intensive application of all other inputs becomes more profitable as well. The driving mechanism of the macromodel is considerably weakened if substantial scope exists for expansion of food output through the application of nonenergy inputs. Indeed, if more acreage is available, more labor-intensive cultivation rewarding, better water control and use more feasible (without pumps), and so on, then the reliance on energy related inputs to meet the demand for food will be substantially weakened.

The extent to which nonenergy options exist for raising food output will depend on individual national (and regional) circumstances. But even where they exist, food prices must rise to call them forth. Thus, the immediate lesson of the macromodel with respect to energy inputs into food production may be substantially altered in those countries with balanced resource endowments. However, the impact is the more general lesson that food production must be profitable in the long run. Development economists' enthusiasm for two-sector models and a transfer of resources from agriculture to industry caused many to lose sight of this fundamental economic reality.

It is easy enough to say that food prices must rise relative to energy (and other input) prices so that growing food remains profitable. What is ignored in the statement is any consideration of the social and political costs involved in the process. Only the commercial farmer is fully protected on the income side in such a world, and even he will have to pay higher real food prices. Two other major segments of society will be affected in a far more dramatic fashion. First, subsistence farmers may not be able to afford the high energy costs despite higher market prices for food. Since they sell little food, they benefit little from the higher price. The subsistence farmer's resource holdings simply may not be large enough to generate the real productivity necessary to be able to "afford" to eat his own production.

Second, the nonfarm poor are obviously the worst off. With no landholdings at their disposal to produce some of the high priced food for their own use, the nonfarm poor must find a means to buy their entire food requirements. In the first instance this usually means cutting back on nonfood expenditures, but since many of the urban poor spend nearly all their income on food already, this offers little hope. A second alternative is to find additional sources of income. But the very logic of the macromodel, that food prices must rise relative to other prices, will make this a frustrating and unrewarding effort. The final solution, grimly final in several countries, is a reduction in food intake and slow starvation for those already on the margin. The suffering and misery involved in this solution are only too apparent at the moment. The political implications, both domestically and internationally, are only now beginning to be seen.

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The Relative Bargaining Strengths of the Developing Countries

Ernest Stern and Wouter Tims

"A particular aspect of economic stability to which special attention must be given is the stabilization of world raw material prices. . . . The unfortunate consequences of large fluctuations in these prices have been particularly evident in the past few years. . . . While the need for avoiding excessive fluctuations will be readily recognized, there is no easy solution that is equally applicable to all commodities" (Organization for European Economic Cooperation, pp. 26–27). This description of the commodity problem could have been written in 1974, but in fact it was written more than two decades ago. The lack of progress since then in dealing with commodity prices—both to reduce the amplitude of fluctuations and to maintain or increase their prices relative to those of manufactured goods—has been a frequent source of friction between the industrialized and the developing countries. Efforts to manage commodity prices through international cooperation have not been lacking but, in general, these have not been very successful. The world economic situation and the actions of groups of commodity-producing countries have heightened the awareness of raw material producers and consumers alike to the possibilities of supply management. Speculation about the chances for success of such actions obviously must be larded liberally with humility derived from the knowledge that a mere three years ago it was held with certitude that a collective effort to raise oil prices was impossible. Nonetheless, it is worthwhile to set out the interrelationships bearing on the access to, and the prices of, primary commodities so that there will be a framework for discussion of alternative scenarios.

The unilateral increase of oil prices, the general commodity price boom of 1972–74, and the concern with the possible depletion of the world's resources is sometimes seen as the beginning of a major shift in power relationships between the industrialized and developing countries. Fred Bergsten called attention to the interaction of these factors as early as the summer of 1973 and recently has expanded on this theme.

The analysis of bargaining strengths is highly complex and many of the factors at play can only be assessed subjectively. Bargaining is a process in which parties with different interests and conflicting objectives attempt to reach an agreement which benefits the parties in rough proportion to their strengths. When applied to relations between industrialized and developing countries, complications arise since the countries of the world are not neatly divided into two such groups. Consequently, wherever this spectrum is divided for analysis, there are multiple objectives within each group. This paper limits itself to the question of how recent economic changes in commodity markets have affected the economic strengths of the developing countries and how the relevant factors are likely to develop in the future.

Current Bargaining Strength

The generally accepted thesis that countries of the developing world have lacked significant bargaining power has been formulated in three dimensions: demand, supply, and degree of essentiality. Contrary assertions and recent experience related to the world market for crude oil are cast largely in terms of the last element, essentiality.

The best-known arguments regarding the lack of bargaining strength of developing countries have been in the trade area (United Nations 1974a). Developing countries depend for their foreign exchange earnings on a small number of primary commodities; these constituted in 1960 more than 90% of their exports and still constituted close to 80% in 1972.

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Table 1. Market Position in Major Commodities of LDC Exporters (1970–72 Average in Percentages)

	Mineral Exporters				Other Developing Countries with Per Capita Income						All Developing Countries	
	Oil Exporters		Other Mineral Exporters		Above $375		$200–375		Below $200			
	Share in Total Exports of Country Group	Share in World Market	Share in Exports	Market Share	Share in Exports	Market Share	Share in Exports	Market Share	Share in Exports	Market Share	Share in Total LDC Exports	Share in World Market
Oil	84	69	—	—	3	2	2	—	4	1	35	73
Coffee	—	—	2	3	8	60	4	9	9	22	5	97
Copper	—	—	62	48	—	—	3	5	1	1	5	54
Sugar	—	—	2	3	3	22	5	12	13	32	4	71
Cotton	—	—	2	2	2	14	7	17	7	13	3	57
Timber	1	3	—	—	2	10	7	10	1	1	2	26
Iron ore	1	5	4	12	1	9	3	8	4	10	2	39
Rubber	1	24	—	—	2	52	2	14	1	6	2	98
Cocoa	1	24	—	—	1	17	6	49	1	8	1	100
Beef	—	—	—	—	3	28	—	—	—	—	1	30
Tea	—	—	—	—	—	—	—	—	7	73	1	83
Tin	1	2	1	4	1	42	3	24	—	—	1	86
Bananas	—	—	—	—	2	66	2	20	—	—	1	92
Other primary commodities	1	1	15	2	9	6	14	3	7	2	8	15
Other exports	10	1	12	—	63	6	42	1	45	2	29	9
Total	100		100		100		100		100		100	
Export weighted market shares		59		31		14		8		14		49
All of the above, excluding oil		—		—		—		—		—		35

Source: International Bank for Reconstruction and Development (1974).
Note: Column 1 under each country category shows the share of a particular commodity in the total export basket of the group; column 2 under each group shows the share of the group's exports in total world trade in the commodity.

Table 2. Developing Countries' Share of World Exports of Primary Commodities for Selected Years

Years	LDC Exports (U.S. $ billion)	World Exports (U.S. $ billion)	LDC Share of World Exports (%)
1955	21.91	54.12	40.5
1960	24.80	67.89	36.5
1965	32.04	90.03	35.6
1970	45.48	132.32	34.4
1971	49.46	142.18	34.8
1972	57.64	166.07	34.7

Source: United Nations (1972, 1974b).

Their dependence on these commodities for exports is not matched by an equally dominant share in the markets for several of these products (table 1). Although a comparison of totals is too simple, it is nonetheless of some significance to note that developing countries' exports of primary commodities were only 40% of world primary exports in 1955, and this percentage declined gradually to 35% in 1970–72 (table 2) in part because of major competition from synthetics and other substitutes. Each period of high prices for primary commodities has led to investments for synthetic substitutes and alternative technologies which capture market shares virtually permanently.

The position of many developing countries has also been eroded by the reduction of the preferences that once applied to major segments of their exports exposing more of their trade to competition.[1] At the same time, nontariff barriers have grown.

Prices have become less predictable in recent years as a consequence of movement toward more flexible exchange rates and more rapid rates of inflation. While some developing countries may benefit from higher export prices for primary commodities, developing countries' imports account for only a small share of the trade in primary commodities and, generally, cannot affect price.

The imbalance in relative positions also is discernible on the capital side. Net capital inflows on concessional terms from official sources now provide only a third of capital required despite a substantial increase in requirements. Today such capital is inadequate to meet the needs of even the poorest countries. In the area of private investment, countries must deal with corporations which have a multinational network of operations, which often are more effective negotiators than the host countries, which may have more alternatives than the host countries, and which provide much of the technology associated with the capital inflows.

[1] This is notably the case for Commonwealth preferences which were eroded by the two successive rounds of GATT tariff reductions and were finally abolished through the United Kingdom's joining the European community.

The Market Outlook

Commodity prices surged in 1973 and 1974 after a period of remarkably stable prices since the Korean War. However, compared to prices of manufactured goods, the prices of primary commodities tended to decline throughout the 1950s and up to about 1962. Between 1962 and the middle of 1972, there were no major changes in the commodity (net barter) terms of trade. More recently, between 1970 and 1973, the rise in commodity prices was far greater than the increase in the prices of exported manufactured goods.

In the course of 1974, prices of most primary commodities have, with few exceptions, begun to soften. This is expected to continue throughout 1975 while demand conditions are weak. Crude oil will remain the most notable exception. Other possible exceptions, but to a much lesser degree, are cereals and sugar.

Measured relative to past and projected price changes for manufactured goods in world trade, most primary product prices (excluding oil) are expected by 1976 to return to their level of the 1960s and to remain there into the early 1980s. The assessment takes account of possible medium-term supply bottlenecks; long-term supply constraints may exist as well but do not affect projected prices by 1980.

The projected prices (table 3) have a differentiated effect by groups of developing countries both because of the composition of

Table 3. Indices of Commodity Prices, 1950–80 (1967–69 = 100)

	Agricultural Products		Metals,		Total
	Food	Nonfood	Minerals	Petroleum	(excluding oil)
1950–52	128	181	77	112	124
1960–62	98	120	77	105	96
1967–69	100	100	100	100	100
1970–72	98	90	86	107	93
1973	111	131	91	139	110
1974	135	123	116	440	133
1975	116	106	100	440	111
1980	98	91	101	400	100

Note: Price projections beyond 1975 are hazardous because of uncertainties with respect to growth in the industrial countries, general price developments in international trade, and the behavior of exchange rates. The 1980 price projections are based on the assumption that growth in the industrial countries will, after 1975, move towards its historical long-term trend and that inflation rates measured in U.S. dollars will gradually abate to 7% per year towards the end of the decade.

their exports and the effects from higher primary commodity prices on such products as oil, food grains, sugar, and cotton. The estimates show the deterioration of the commodity terms of trade of all non-oil developing countries which occurred in 1972 as compared to the base period 1967–69. Countries with a substantial component of manufactured goods in their exports did better on the average through 1972. The improvement of the terms of trade for all non-oil developing countries in 1973 amounted to some 4%, mainly in countries dependent on exports of primary commodities.

In 1974 there was a major deterioration of the terms of trade. Although export prices of manufactured products and primary commodities rose further (the estimated average export price increase was 14%, following on an increase in 1973 of 34%), this was not sufficient to offset the unprecedented increase of import prices which is estimated at 32%. The oil price was a major element in this increase (on the order of eighteen percentage points), followed by manufactures (contributing ten to eleven points). Although the average deterioration of the terms of trade for the non-oil developing countries was shared about equally among all of these countries, it followed a significant earlier improvement in 1973 for those at the higher income level with sizeable exports of manufactured goods; for the lower income countries, by contrast, it came on top of a small deterioration in the preceding year.

The projections for 1975 foresee little or no change in this situation. For the remainder of the decade a slight recovery is foreseen on average. By 1980 the terms of trade will still be about 8% below the level of the 1960s. The lower income countries are expected to experience a continuing deterioration of their terms of trade beyond the colossal decline of more than 20% between 1967–69 and 1974. Although the losses of the east and central African countries are severe, the outlook for the south Asian countries is far worse. As the south Asian countries comprise about 45% of the total population of the developing countries, this is clearly a principal issue for international economic policies in the years ahead.

The penultimate column of table 4 projects export growth rates, in volume terms, corrected for changes in the terms of trade, representing the annual rate at which the purchasing power of each country group's export earnings are expected to increase. Again, the lower income countries show the smallest growth in capacity to import.

Bargaining strength of the developing countries must be viewed against this background, which suggests that one major objective would be to avoid the terms-of-trade decline now projected and/or provide greater long-term price stability rather than to raise prices above recent levels.

Market Aspects of Primary Commodities

The concerted action to increase the price of oil in December 1973 is generally seen as an example of actions which may lie ahead in other areas. In response to rapidly growing demand, production of oil grew at an average annual rate of over 7% between 1955 and 1973. Limited possibilities in the medium run to substitute for oil are reflected in low demand elasticities, although even in the short run these cannot be entirely neglected: higher

Table 4. Import and Export Prices and the Terms of Trade by Country Groups, 1972–80 (1967–69 = 100)

	1972	1973	1974	1975	1980	Adjusted Export Growth Rate (%) (1972–80)[a]	GDP Growth Rate (%) (1973–80)
Mineral exporters (excluding net oil exporters)							
Export price	105	155	174	188	296		
Import price	118	152	197	209	296	8.1	6.1
Terms of trade	89	102	88	90	100		
Higher income countries (above $200 per capita)							
Export price	114	154	177	190	276		
Import price	115	149	196	207	293	7.0	5.9
Terms of trade	99	103	90	92	94		
Mediterranean							
Export price	121	156	175	188	273		
Import price	121	155	203	215	303	7.9	7.0
Terms of trade	100	101	86	87	90		
Latin America							
Export price	123	161	189	202	297		
Import price	112	145	188	200	284	7.0	5.4
Terms of trade	110	111	101	101	105		
East Asia							
Export price	94	138	159	171	240		
Import price	112	147	200	211	299	5.9	6.0
Terms of trade	84	94	80	81	80		
West Africa							
Export price	106	162	176	189	292		
Import price	114	147	194	206	292	6.5	6.4
Terms of trade	93	110	91	92	100		
Lower income countries (below $200 per capita)							
Export price	113	141	160	169	232		
Import price	115	148	201	213	302	2.1	2.8
Terms of trade	98	95	80	79	77		
East and central Africa							
Export price	116	155	182	191	269		
Import price	121	152	204	217	309	4.0	3.7
Terms of trade	96	102	89	88	87		
South Asia							
Export price	111	135	149	159	215		
Import price	113	147	200	211	299	1.2	2.7
Terms of trade	98	92	75	75	72		
Total non-oil developing countries							
Export price	113	152	174	187	273		
Import price	115	149	196	208	295	6.5	5.15
Terms of trade	98	102	89	90	93		

Source: International Bank for Reconstruction and Development, estimates and projections.
Note: The average terms of trade for the 1967–69 base period are about equal to those for the entire decade of the 1960s.
[a] At constant prices and annual rates, adjusted for terms of trade changes.

prices do reduce consumption. The low demand elasticities reflect the fact that consumption patterns are built into the capital structure (e.g., transportation network, power supply facilities, and the stock of cars by sizes) and will take time to alter. In terms of essentiality, there is hardly an internationally traded commodity which can rival oil.

The supply of oil in international trade is concentrated in a few countries. In 1973, an embargo and a large price increase met the political objectives of one group of oil produc-

ers, while the price increase was supportive of the economic objectives of another. This coincidence of objectives made supply management feasible. Further, supply restrictions can be implemented at little or no cost as oil can be retained in the ground, and the employment impact of production cutbacks is negligible. Limits on alternative supplies put a horizon of some seven to ten years on the capacity of the oil suppliers to maintain prices. The reduced role of the major oil companies during the 1960s strengthened the supplying countries.

This set of characteristics of oil in the world economy needs to be compared with those of other primary commodities. The principal "lesson" of the oil price is that the lesson is not clear; the experience is far from completed. It is too early to assess the benefits from the viewpoint of the oil producers, quite aside from how they may be affected by the economic problems in the industrialized countries and the strains which are evident in the international financial system, or to evaluate the impact on earnings in the long term. The expected price of oil, combined with considerations regarding security of supply, will determine to what marginal cost levels the oil-importing countries are willing to go in the production of substitutes. The higher the oil prices and the greater the certainty that they will remain at high levels, the lower demand and the larger the investments for substitute energy supplies and the greater the risk that the substitution will become irreversible. Similar risks do exist with other products, and the extent of the risk depends on the state of technology of substitutes, the amounts of capital and other factors of production required to produce these substitutes in significant quantities, the demand elasticity (the essentiality) for the commodity, and the time horizon associated with the investment and production of substitutes combined with the discount applied to future earnings. Exporting countries also need to take account of the scope trading partners have for price increases which may negate the benefits of their own action.

Supply Position of Primary Commodities

The average value of exports of primary commodities from the developing countries was $50 billion in 1970–72; almost $20 billion was crude oil. Of the remaining $30 billion, the next five most important accounted for $10 billion: coffee, copper, sugar, cotton, and timber. Another $10 billion of developing countries' exports consisted of some thirty primary commodities; the remaining $10 billion was composed of a very large number of minor items, none of which had an export value of more than $100 million.

Commodities for which developing countries control a share of internationally traded supplies comparable to the case of oil (i.e., more than 70% of world trade) are numerous, but for most, the value of trade is small so that the effort to control supplies, even if effective, would yield little benefit as compared to their organizational and administrative costs and effects.

There are only twelve commodities for which developing countries' exports exceeded $500 million in the 1970–72 period; of these, the developing countries controlled a major part of total supplies for only seven. Their main characteristics are shown in table 5.

The seven major export commodities. The seven products for which developing countries have an equal or larger share in world trade than they have in the case of oil have other supply characteristics which make those commodities less susceptible to supply management. If only control of supplies and the capacity to store the product are considered, the best prospects for supply management are in rubber and tin. The poorest long-term prospects seem to exist for the tropical beverages.

Two countries (Malaysia and Indonesia) control more than 70% of export trade in rubber; storage is possible at acceptable costs, and it takes some five to six years for rubber trees to mature. But the existing production capacity for synthetic rubber, which already supplies 68% of the market, would make supply management very difficult. A managed price would come under pressure from additional manufacturing capacity leading to a larger market share for synthetics.

Four producers (Malaysia, Thailand, Indonesia, and Bolivia) control more than 70% of international trade in tin, and world trade is 88% of world output. Storage is not expensive, as is demonstrated by the low costs of operation of the international tin buffer stock. In this case two factors obstruct supply management. The size of the U.S. stockpile approximately equals a year's world consumption (211,000 tons versus 250,000 tons), and there is competition from aluminum, tin-free

Table 5. Developing Countries' Position in Trade of Twelve Major Primary Commodities (Averages for 1970–72)

	1970–72 LDC Share in World Trade (%)[a]	Number of LDC Suppliers Accounting for at Least 70% of Total Trade	World Trade as % of World Production 1970–72	Gestation Period for New Investments (Years)	Synthetic Substitutes as % of Total Supplies	Storage Possibilities
70%–100%						
Coffee	97	10	71.5	6–7	—	limited
Sugar	71	30	27.2	3–4	negl.	limited
Rubber	98	2	90.7	5–6	68	yes
Cocoa	100	4	78.0	6–7	—	limited
Tea	83	6	58.3	5–7	—	limited
Tin	86	4	87.7	2–4	—	yes
Bananas	92	9	20.3	1–2	—	no
50%–70%						
Copper	54	—	58.1	4–5	—	yes
Cotton	57	—	32.3	1–2	54	yes
Less than 50%						
Timber	26	—	8.3	—	—	yes
Iron Ore	39	—	41.4[b]	4–5		yes
Beef	30	—	5.2	2–3		limited

[a] Gross exports.
[b] Based on 1970–71 trade data.

steel and plastics in some of the main end uses of tin.

The three tropical beverages (coffee, tea, and cocoa) can be considered as a group, within which substitution can be of significance.[2] For each of these products a small number of suppliers control a major part of world output and most countries dominating the supply of one of these commodities are also important producers of at least one of the other two products. Gestation periods of new investments in the three crops are five to seven years; storage is, however, costly and losses can be substantial particularly in terms of quality.

Past efforts at international agreements for these three commodities with the objective of managing supplies to stabilize prices have proved difficult. No international tea agreement has been feasible because of disagreements between traditional and new producers about market shares. In the case of cocoa, an agreement became effective in 1973 after fourteen years of negotiation, but no action has been necessary as the market price was (and probably will remain for some more years) considerably above the agreed intervention points. No buffer stock exists as yet. For a number of years, the Coffee Agreement has had the appearance of a successful operation, but this was largely achieved through the self-imposed restraint of Brazil which held large stocks and also reduced its share in world production and exports considerably over time. Thus, a large number of small producers, many of them newcomers to the coffee market, could expand their exports while prices gradually rose as a result of Brazil's coffee policies.

The market situation for sugar is more complex, and negotiated prices have governed a portion of exports. Although developing countries supply a major share of world trade, the bulk of sugar production in the world is for domestic consumption. The share in world trade is therefore a poor indicator of market strength; a better measure is the share of developing countries' exports in world sugar consumption, which amounted to only 21% on average in 1970–72 and which is shared by no less than thirty countries.

Efforts at joint action on supply by banana producers are in process. The supply characteristics of the market, in terms of the possibility of joint action by producers, are mixed. Bananas have been in chronic oversupply which has permitted the few companies which

[2] Efforts to demonstrate the degree of substitution between these three commodities have, however, been largely unsuccessful.

dominate the collection, transport, and distribution to be highly selective in their procurement from sources other than their own plantations. However, if major producers can form a united front, the limited number of companies involved would enhance the bargaining strength of producers. Effective action must include a rigorous quota system and limitations on production which have not yet proved possible. The need to limit production is the more essential because it is impossible to store bananas.

The seven major commodities discussed above, except tin, and labor-intensive agricultural products, and supply management has therefore significant consequences for employment and often for regional incomes.

Five additional important commodities. For the five other major commodities of which developing countries' exports exceeded $500 million in 1970–72, their share of world trade is less than 60%. In the case of cotton, beef, and iron ore, trade is relatively small compared to world production so that the points raised above in respect of sugar apply here as well. Timber and copper prospects are more promising.

The share of developing countries in world timber trade does not reflect their true market strength. Tropical hardwoods constitute a market of their own within the timber trade because of their particular end uses and because supply is concentrated in a few southeast Asian and west African countries. The main producers in southeast Asia have already announced their intention to place strict limits on the production of tropical hardwood logs, dictated largely by the need to avoid depletion of these timber resources. An already existing scarcity will consequently become more severe, and prices will rise even though the development of substitutes will accelerate.

The international copper market is one in which suppliers could obtain limited benefits since the expansion of copper mining and processing is costly and requires long lead times. The four major producers (Zambia, Zaire, Chile, and Peru) could effectively influence the supply in the world market if the developed country producers (United States and Canada) did not seek to undermine the effort. The recent announcement by the four major exporters of a 10% reduction in copper shipments indicates their willingness to act in a joint fashion, although this reduction is thought necessary to halt the precipitous price decline.

The production of copper from scrap is, however, of some importance, particularly when higher copper prices would stimulate recovery from scrap. Moreover, world copper resources are large and a substantial part is in the industrialized countries. Exploitation of those resources would become attractive with a high price of copper. Both factors suggest that benefits of price management would accrue only for a limited time.

Supply Policies for Major Minerals

Supply management for the major minerals and metals will benefit only a small number of countries. The four major minerals (bauxite, copper, manganese, tin) accounted on the average in 1970–72 for less than 6% of total exports of the developing countries. There are in total only ten countries for which these commodities are of significance, mainly higher income developing countries.

Table 6 compares the rates of growth in production of the major minerals with those of oil since 1955. Even where technological substitution is feasible, producers of a commodity in consistently strong demand obviously are in a better negotiating position than producers of other commodities. Of the major minerals, production of bauxite and related products and phosphate rock grew at about the same rate as oil output.

In terms of the possible impact on international prices and on export earnings, the significance of these commodities also is much less than that of oil. Average annual exports by developing countries in 1970–72 amounted to $3–4 billion, whereas oil exports from the developing countries amounted to $20 billion. The price increase between that period and 1974 added $75–80 billion to the revenues of the oil producers, but for the other minerals a similar price increase (which in any case is an unlikely scenario) would add at most $13 billion to export earnings. For the minerals, the expectation is that prices in constant dollars will remain above the 1967–69 level, and there may be possibilities to mitigate a decline from the high 1973–74 price levels either through joint action or through unilateral price leadership.

The action of producers to manage supplies in order to raise prices need not be limited to developing countries. If developed country producers, such as Australia, Sweden, and Canada, were to join in the effort, mineral

Table 6. World Production of Selected Minerals, 1955–73

	1955	1960	1965	1970	1972	1973[a]	Average Annual Growth Rates 1955–73 (%)
Crude petroleum (1000 bbls.)	5,016,972	6,466,650	9,070,507	14,899,300	16,406,750	17,766,375	7.3
Metals and minerals (1000 m.tons)							
Nonferrous							
Copper	3,112	4,242	5,066	6,374	7,049	7,519	5.0
Bauxite	17,760	27,620	37,292	59,484	68,860	73,134	8.2
Alumina	6,200	9,300	13,600	21,095	23,440	26,183	8.3
Aluminum	3,105	4,528	6,586	10,207	11,513	12,708	8.1
Lead	2,178	2,376	2,750	3,438	3,452	3,477	2.6
Tin (tin cnt.)	194	189	191	219	232	223	0.8
Zinc (gross wt.)	2,967	3,351	4,229	5,333	5,477	5,670	3.7
Iron ore (Fe cnt.)	174,500	222,100	325,000	417,700	417,700	468,000	5.6
Manganese ore (Mn cnt.)	4,709	5,524	6,797	7,900	9,014	9,699	4.1
Phosphate rock	28,591	39,445	60,375	81,074	88,819	98,776	7.1

Source: The British Petroleum Company Limited; International Bank for Reconstruction and Development (1971); Metallgesellschaft; United Nations (1974a, 1974c, 1974d); U.S. Bureau of Mines.
Note: Crude petroleum data exclude centrally planned economies.
[a] Preliminary.

producers would be in an extremely strong position to set prices of their exports.

The Demand Structure and Essentiality

The main markets for primary commodities are the developed countries. Significant differences between the twelve major commodities relate partly to the geographic distribution of demand and partly to demand response to price. The geographic distribution of imports is heavily weighted by Western Europe and North America, and in the case of minerals also by Japan (table 7). For tea, cotton, and sugar, the developing countries themselves are major importers; the centrally planned economies are a sizeable market for rubber, cotton, and sugar. This would suggest that, because of the "spread" of importing countries, the bargaining position of consumers is relatively weak in the cases of sugar, tea, cotton, and rubber, but this conclusion needs to be drawn with caution. The sugar market is dominated by production for domestic use and further characterized (at least through 1974) by three major preferential arrangements. The tea market is dominated by one consumer, the United Kindgom.

The demand for tropical beverages, except for tea, is heavily concentrated in North America and Western Europe. The income and price elasticities tend to be low in those markets, at least within historical price ranges. Price increases for these products would therefore likely benefit producers as these would be only partly offset by a reduc-

Table 7. Shares in Value of World Imports of Major Primary Commodities (1970–72 Average in Percentages)

	U.S. & Canada	Western Europe	Japan	Other Developed	Centrally Planned	Developing	Total
Coffee	39	50	2	1	4	4	100
Sugar	29	24	11	1	17	18	100
Rubber	20	32	9	3	27	9	100
Cocoa	24	50	3	2	18	3	100
Tea	11	41	3	6	8	31	100
Tin	29	41	14	—	6	10	100
Bananas	27	47	18	1	2	5	100
Copper	9	64	19	—	3	5	100
Cotton	2	32	18	1	26	21	100
Timber	15	42	25	2	5	11	100
Iron Ore	13	39	36	—	11	1	100
Beef	30	58	2	1	4	5	100

tion in the volume of demand, and consuming countries could retaliate with indirect taxes as these products are not essential. Higher prices could also accelerate the consumption of substitutes, in particular the soft drinks which have rapidly increased their share in the market. Long-run benefits from price increases are therefore quite uncertain.

The possibilities in the case of sugar are minimal. The only way for developing countries to increase their earnings from sugar is to press further for trade liberalization as sugar production in many developed countries involves high costs and takes place behind protective shelters. Liberalization would reduce such production and increase the demand for sugar produced in the developing countries.

Rubber and tin, although consumed in a large number of countries, face competition from substitutes which suggests that unilateral supply and price management for any extended period is not feasible. The same factor applies to cotton, but imported cotton also has to meet the competition of production of cotton in North America. Beef exports, too, must compete with beef production from the developed countries. In general, removal of nontariff barriers could be far more beneficial than any attempt to raise prices unilaterally.

This leaves three commodities of a more essential nature from the importers' point of view: copper, tropical timber, and iron ore. An interesting feature of all three is the relative importance of the Japanese and Western European markets which account for some 70%–80% of world imports of these three commodities. This concentration of demand strengthens the bargaining position of the producing countries.

Timber prices were stable in real terms throughout the 1960s. A high income elasticity and a relatively small response to price in the consuming countries have led to a situation where the few producing countries are rapidly gaining bargaining strength and are now ready to use this to their advantage.

Next to timber, copper offers the most interesting case. Supply restrictions and higher prices by the major developing copper producers would bypass the United States and Canada which have undeveloped copper resources but be felt by Western Europe and Japan which depend on imports for more than 90% of their copper consumption.

Iron ore is in a weaker position since demand for ore has not grown at the same rate as steel production due to increasing use of scrap. Increased input flexibility of steel mills could further weaken the position of the suppliers of ore. However, some strength derives from the increased vertical integration through use of pelletization processes and special carriers and from the dominance of trade under long-term contracts.

Secondary Effects of Price Action

Price action for export commodities must, of course, be seen in context. While it increases the revenue to the producing countries, it reduces the income of others. The increased cost of raw materials will be reflected in the finished products which the primary exporters import. The net gain to the exporters will thus depend on the share of the commodity subject to price action in total exports versus the cost increase in the manufactured goods component of imports. Since, in general, developing countries have trade deficits and since a country exporting a single primary commodity obviously imports finished products which may reflect price increases in several primary products, the offset could be substantial. Although the bulk of the reduction in real income will fall on the principal consumers, part of both the direct and the indirect effects will fall on the developing countries.

These factors do not militate against an increase in price where this is feasible, since primary commodity producers cannot be expected to take a more global view of the pricing of their product than producers of other commodities. They can argue legitimately that other mechanisms should be found to support and accelerate the growth in real income in other developing countries. Nonetheless, the results need to be borne in mind since they suggest that the potential bargaining capacity of one group of countries cannot be equated with improvement of the welfare of the developing countries in general.

The Broader Objectives of Bargaining

The conclusion of the preceding analysis is that only a few primary commodities show characteristics which would support the possibility of raising prices through arrangements among producers. The countries which produce the commodities for which some pos-

sibilities may exist belong to country groups which already have made significant development progress, while the countries experiencing the greatest difficulties also have the least capability of mobilizing their own resources for growth. As these countries have the major part of the population of the developing world, they represent the major problem of economic development. Changes in bargaining strength between countries have not made that task any easier. Quite to the contrary, the problems of the low income developing countries have been exacerbated by the improved bargaining power of other developing countries. When discussing the effect of improved bargaining strength on the totality of the developing world, the skewness of the distribution of likely benefits and costs must therefore be taken into account.

On the assumption that prices for some commodities can be raised through supply management, the next question is whether this can be translated into bargaining power related to broader economic or political objectives. Commodity prices are a poor bargaining tool for this process since successful negotiations imply a commitment to a production policy which may not be profitable over the long term, and presumably few countries would be prepared to sell commodities at prices below those which they could otherwise obtain. At most, the producers could promise not to restrict output through administrative measures, but even then they would be reluctant to forego the possibilities of price stabilization agreements which might involve production controls. Thus, as far as price is concerned, the bargaining of the producers must rest on a threat to raise prices. As discussed earlier, the level to which prices can be raised is limited by a number of factors.

In terms of non-commodity-related objectives, access is more important than price, though there are obvious links between the two, short of an embargo. In the case of oil, the embargo was in support of a political objective shared by several OPEC members who also are among the principal producers. In that case, the geographic concentration of oil reserves was a crucial factor since it coincided with a major regional political issue. Other minerals are not as concentrated, so it is rather difficult to envisage an analogous identity of political purpose. Moreover, the dependence of many of the mineral exporters on current export earnings makes such an action, if not unlikely, at least much more expensive.[3] Nonpolitical issues, e.g., general trade relationships, the SDR link, voting rights in international institutions, or aid flows, are unlikely to be made so confrontational as any embargo action inevitably implies.

In assessing bargaining strengths and objectives at any level, it is of course important to assess the strengths of both sides. While economic power is considerably more diffused than in the 1950s, if the issue is drawn between primary commodity producers and other countries, the overwhelming economic strength lies with the latter, including control over major raw material supplies. The developing countries as a group remain heavily dependent on the industrialized countries for markets, for research and technology, for investment goods and, to an increasing extent, for such strategic requirements as food and fertilizer. If it is legitimate for governments to limit production in order to set the export price for a primary product, it would be equally legitimate for governments to seek to maintain the prices of wheat, fertilizer, or generating equipment. Bargaining in an interdependent world only can take place in a framework of mutual interests and benefits.

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[3] There is, of course, the possibility of oil-exporting countries financing commodity stockpiles to support drastically higher prices while offsetting the domestic impact of reduced production or even financing imports in support of a prolonged embargo. Quite aside from the question of whether large-scale investing in commodity futures is a prudent use of funds derived from a diminishing resource, this type of major confrontation almost surely would evoke retaliation.

Domestic Adjustments to Higher Raw Material and Energy Prices in Less Developed Countries

T. L. Sankar

The sudden and unexpected increase in the price of oil and its products and the relatively more gradual increase in the price of several raw materials have created serious imbalances which call for urgent domestic and external adjustments in all countries, developed as well as developing. This paper attempts to briefly survey the extent of the increase in energy and raw material prices insofar as they affect the developing countries and to examine the feasibility of domestic adjustments in these countries. It is difficult to discuss the issues with any degree of specificity due to the variations in the relative affluence (or poverty) of the developing countries, the diversity of their resource endowments, the wide variations in their technological capabilities, and the uncertainties regarding future oil and other raw material prices. The discussion is, therefore, vague and generalized and is meant only to stimulate further examination of these issues.

Nature and Magnitude of the Problem

The examination of the impact of increased prices of energy and raw material has to be seen in the context of the increase in the price of other goods. The prices of manufactured goods exported by developed countries, which rose by less than 6% in the decade of the sixties, have risen by more than 10% annually since 1970 (see table 1). The prices of primary commodities, which constitute the major exports of developing countries, showed remarkable stability until 1971 but increased significantly in 1973 and 1974 (see table 2).

An analysis of the effects of such violent price changes on the developing countries would involve the determination of the price changes country by country, the changes in the volume and commodity composition of trade. A somewhat crude analysis could be done by applying the commodity prices of 1974 to the trade statistics of 1970 to see the hypothetical effect of the price changes if the volume and commodity composition of trade of different countries had remained unchanged from 1970 to 1974. Such a study (United Nations 1974) indicates that the trade balance of the developed countries changed from a deficit of $8.4 billion to $82.1 billion.[1] The developing countries whose trade was in near balance in 1970 show an increase in trade surplus of $60 billion. But the entire increase in the surplus of the developing countries and something more accrue to the oil-exporting developing countries which show an increase in trade surplus from $8.6 billion in 1970 to $77.8 billion. The deficit in the trade balance of the non-oil-exporting developing countries (hereafter referred to as the other developing countries) registers an increase from $8.5 billion to $17.4 billion, which is 30% of their imports in 1974 prices.

In order to make the analysis operationally meaningful, it is necessary to disaggregate the developing countries (especially the non-oil-exporting countries) into subgroups. Though it is possible to effect such disaggregation in terms of their endowment of resources (particularly energy and mineral resources) or their relative technological capabilities or the variations in their GNP, for the purpose of this paper, the developing countries are classified into four categories as follows: (*a*) oil-exporting developing countries, (*b*) other developing countries with higher income per capita GNP above $340 in 1971, (*c*) other developing countries with middle level income per capita GNP between $200 and $340 in 1971, and (*d*) other developing countries with lower income per capita GNP below $200 in

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[1] In this paper, $ refers to U.S. dollars in current terms.

Table 1. Index of Export Prices of Developed Countries

	1956	1968	1972	1973	1974
Index (1968–69 = 100)	94	98	128	154	175
Percentage change per year over figures in previous col.	—	0.4	6.9	20.5	14.0

Source: McNamara.
Note: An index of capital goods and manufactured export prices of major developed countries. The index also reflects changes in exchange rates.

Table 2. Index of Export Prices of Primary Commodities (1967–68 = 100)

	Index of Prices				
Commodity	1970	1971	1972	1973	1974
Food and beverages	115	116	131	181	297
Agricultural raw materials	95	92	115	201	213
Minerals and metals	111	102	104	146	175
All commodities (except petroleum)	108	105	119	176	244
Petroleum	96	123	139	200	665

Source: International Bank for Reconstruction and Development.

1971. A representative selection of groups (*b*) to (*d*) was made, and the effects of the price increases on their trade balances were examined.[2]

On the basis of the sample chosen, it is found that the price increases have affected the medium income countries most, while the higher income group countries have been the least affected among the other developing countries (see table 3).

Possible Responses

The increase in deficit could be balanced either by inflows of capital resources from other countries or by an increase in their terms of trade or by adjustments in their production, consumption, and trade plans. If the prices of the exports of the other developing countries could be increased immediately to the levels which will neutralize the increase in the prices of their imports, the problem is solved at once. But if the terms of trade improve gradually in the next few years, the problem of increased prices will become a transient one and could be tackled by domestic adjustments of one kind. If, however, the terms of trade as in 1974 are likely to continue throughout the foreseeable future, domestic adjustments of a more enduring kind must be made. The single most important factor which will determine the nature of the response of the other developing countries to the increased price of oil and raw materials is their perception of the terms of trade that will face them in the coming years.

[2] The countries selected and their population are set out in appendix table 1.

Terms of Trade

The major export commodities of the other developing countries are some minerals and agricultural raw materials, whose demand is a function of industrial activity in the developed countries, and tropical agricultural consumer products (like sugar, coffee, and cocoa), whose demand is dependent on the levels of consumption in the affluent countries. All indications are that the industrial activity in the developed world will not increase at the rapid

Table 3. Increase in Trade Deficit between 1970 and 1974 of Selected Developing Countries

	Trade Deficit in			
Category	1970	1974 Prices of 1970 Data	Increase in Trade Deficit	Col. 4 as % of Col. 2
1	2	3	4	5
		(in $100 million)		
Non-oil-exporting developing countries with:				
Higher income	31.4	55.7	24.3	77.4
Middle-level income	6.5	16.2	9.7	149.2
Lower income	13.9	28.8	14.9	107.2

Note: For details see appendix tables 2 and 3.

rates witnessed in the last decade. While the increased affluence of the oil-exporting countries will push up the demand for certain tropical products like sugar, coffee, and cocoa, the size of the population which would exert pressure on their demand is too small (300 million) to effect changes in the volume and price of the exports of the other developing countries to an extent adequate to compensate for the increased prices of their imports. In sum, there are no pointers as of now to suggest on purely economic considerations that the terms of trade of the other developing countries will improve significantly from the 1974 position. In fact, a more detailed analysis of the medium-term price trends up to 1980 leads to the conclusion that the terms of trade are likely to deteriorate further.

Transitional Adjustments

If the terms of trade do not improve for the other developing countries, there will be a net outflow of resources from these countries amounting to about $10 billion or 3% of their GNP. This has to be financed by a reduction in their consumption or investment. Reduction in investment, in sum, alters future consumption. Such reduction could be avoided temporarily by drawing on reserves or postponed for a time by obtaining foreign funds either on commercial terms or as aid. The reserves of the other developing countries add up to $32 billion of which nearly 50% is with the higher income developing countries. The average borrowing in the bond markets of the world by developing countries has increased to nearly $6 billion a year, but a substantial portion of such borrowing is by the higher income groups and a few of the middle income group developing countries. The official bilateral development assistance (ODA) disbursed to the other developing countries during 1969–72 has been on the average only $3.6 billion of which over 50% went to the lower income developing countries. Unless the past trends are drastically changed, the higher and medium income countries may be able to postpone for a short time the reduction in investment or consumption by drawing from reserves or by commercial borrowing while the low income countries will have to depend on development assistance for such postponement.

Funds obtained either on commercial terms or as aid can only postpone the reduction in consumption or mitigate the level of reduction, as even funds obtained as aid have to be returned at some date. The terms under which such funds flow to the developing countries will determine the extent to which the consumption will be reduced. But such capital flows, obtained on reasonable terms, will provide the necessary "time" required by the developing countries to effect enduring domestic adjustments.

Domestic Adjustments

The rational domestic adjustments of the other developing countries in response to the increased prices of energy and raw materials would be towards exploitation of the new indigenous production and international trade possibilities opened up by the new price relatives of 1974; in short, the increased price of energy and raw materials would change in many areas the comparative advantage of the other developing countries vis-à-vis the other countries, making many activities economically efficient now. Rational domestic adjustment would be towards harnessing the new economic opportunities in all the sectors of the economy. We will examine the energy, minerals, agricultural, and manufacturing sectors.

Energy Sector

The most promising of these domestic adjustment options appears to be the restructuring of the pattern of fuel production and usage. Because of the low price of petroleum during the 1960s, the average cost of energy was low and energy consumption increased at a high rate; of the different fuels, the share of oil increased rapidly. While energy consumption increased at the rate of 6.16% in the developing countries during the 1960s, their dependence on imported fuels increased more rapidly. The degree of independence of a country in the energy sector can be measured by the "cover coefficient" defined as the ratio of the primary energy production in a country to its total energy consumption. Among the developing countries only a dozen have a cover coefficient over 50%, and of these all except India have a significant production of oil and natural gas (see table 4).

The low cover coefficient indicates the de-

Table 4. Cover Coefficient of Developing Countries, 1970

Country	Cover Coefficient (%)
Non-oil-exporting developing countries (all), of (1)	66.6
Higher-level income countries	72.3
Middle-level income countries	34.2
Lower-level income of 4	74.9
India	88.9
Others	45.2

Source: United Nations (1968–71, table 2).

gree of dependence on imported energy which is mostly oil. In view of the increased oil price, countries with a low cover coefficient would immediately face a large increase in the average costs of energy and would tend to make immediate adjustments which are energy saving. It is generally argued that the per capita consumption of energy is so low in the developing countries that there will be no room for further reduction. This argument has to be weighed against the fact that the elasticity of energy consumption to GNP growth is substantially higher in the developing countries as compared to the developed countries. This was 1.5 in the case of developing countries in the decades of the 1950s and 1960s, while it is only 1.0 in the case of developed countries. This is partly explained by the relatively lower efficiency of utilization of fuels in the developing countries and the once over shift from manual and animal power to machines in the early stages of development. In several developing countries, especially those in the lower income group, it may be possible to postpone the pace of mechanization. In all developing countries it is possible to reduce the level of energy consumption without reducing the production plans by improving the energy utilization efficiency. But such rational reduction in energy consumption will call for a detailed survey of the equipment used in different industries, identifying wasteful practices and equipments, installing improved equipment, and training the staff. It is estimated that such measures will take two to five years to implement fully and may result in about 10% reduction in energy consumption.

Most of the developing countries can also substitute imported energy by indigenous energy; such interfuel substitution is possible in the energy-producing as well as energy-consuming sectors. In the energy-producing sector, secondary fuel (mainly electricity) can be produced from any of the primary fossil fuels like coal or oil or from the exploitation of hydroelectric potential or nuclear energy. But on examining the relative costs of these options, it is found that compared to oil-based power generation, other modes are more capital intensive and, except for coal-based power generation, others also involve longer construction time and call for higher technical skills. Nuclear power generation is also sensitive to scale of operation. The cost of power generated in a 100 megawatt nuclear plant is equal to the cost of oil-based power generation when oil is priced at $9.30 per barrel, while power generated in a 1000 megawatt nuclear plant has costs equal to oil-based power generation when oil is priced as low as $3.99 per barrel (Lane and Roberts). But a 1000 megawatt nuclear power plant can be introduced only in a power system which has a total generation of at least ten times that capacity. All these facts suggest that only the other developing countries in the higher income group may be able to effect any significant shift in favor of indigenous fuels, and among the lower income group only a few like India, whose total energy demand is high and who have a diversified technological base, can opt for such interfuel substitution on any significant scale.

In the energy consumption sectors, the possibility of economically meaningful interfuel substitution has to be examined with reference to purposes for which the fuel is used and the thermal efficiency achievable in each case. The efficiency of fuel use varies with the sector and within each sector (like the transport sector) with the technology adopted. It is therefore difficult to forecast the direction and pace of interfuel substitution possible in different developing countries. The studies made with reference to the Indian conditions indicate that except for the limited possibility of substituting oil for direct use of coal as in the case of heat raising in industries and power generation, the other possibilities of substituting oil by indigenous fuels require the prior transformation of coal to electricity or to coal gas which is very capital intensive. It was also found that these options cannot be considered separately as there are interrelationships among the options. The optimal set of interfuel substitutions may have to be determined for each country by simultaneously examining all the options.

An example of such a study undertaken by a developing country is the *Report of the Fuel*

Policy Committee of India. This study has sought to determine the optimal pattern of fuel utilization in the light of the current relative price of fuels. The Committee found that though most of the substitution options in favor of coal were economically desirable, institutional and resource constraints will limit the pace of substitution in the near future. A comparison of the likely demand for different fuels if no action for interfuel substitution is initiated and the likely demand if suitable measures towards optimization of fuel usages are adopted as given in the report shows that a reduction in the consumption of oil at the end of the first five years is only 11.6% and by the end of 1990 it is 26.5%.

If we generalize from the studies on the Indian situation, the problem of effecting optimal interfuel substitution in many developing countries (with fuel resources other than oil) is likely to be one of finding necessary investment funds to undertake import substitution projects in the fuel sector. The benefits of measures taken in this direction will become significant only after five to ten years.

Mineral Sector

The comparative advantage of the developing countries in the mineral sector has changed due to the increases in the prices of minerals and metals, and in most of the developing countries considerable efforts for modifications in the rate and pattern of production in this sector would be made. However, the possibilities of increasing the exports of minerals will be limited by the demand for such minerals in the developed countries. There has been a very close relationship between the rate of growth of developed countries and the mineral exports from the developing countries. If the developed countries grow at less than their anticipated rates, the volume of mineral exports required by them would be less than what would have been planned for in the earlier perspective. Further, the growing awareness of the environmental aspects of mineral utilization and the consequent trend towards designs of equipment and consumer articles which involve the use of fewer metals and which lend themselves to easy recycling adds another dimension to the market uncertainties. As there is a large gestation lag in mineral development, varying between five to ten years depending on the nature of the mine and the knowledge about mineral deposits already available, a major portion of the future requirements of minerals for the developed countries would have been planned for already. The extent of advance planning is quite significant in mineral and metal production where the industry is dominated by a handful of multinational corporations with high vertical integration of mineral and metal production. Any reduction in the demand as against earlier expectations is likely to affect the prospective market for mineral producers, especially the new ones who do not have links with the multinational corporations.

Agricultural Sector

Besides oil and raw materials, the prices of goods and beverages have also increased sharply during 1973–74. The other developing countries as a whole are net exporters of food and beverages. The exports of these countries consist predominantly of tropical products like sugar, coffee, cocoa, and tobacco, while their imports are mostly food grains and soybean and milk products which are primarily produced in the temperate zone. Countries which are major exporters of tropical products appear to be in a position to benefit from these price changes in the long run. Increasing food grain production (wheat, rice, etc.) for import substitution in spite of several difficulties can be attempted. The agro-climatic conditions, the pattern of land ownership and tenure, the lack of adequate research and development in the production of proper seeds, and the lack of adequate quantities of fertilizers and pesticides which have constrained food grain production in the past will continue to operate even in the face of the changed prices. In spite of these factors, during the 1960s many of these countries increased the production of cereals significantly by adopting the Green Revolution techniques of utilizing the new miracle seeds, backed up by a reliable water supply from irrigation systems and by the use of chemical fertilizers and pesticides. Still, the average yield of cereals in the developing countries is about 40% of the yield in the developed world.

In the other developing countries with large populations and surplus rural labor, there are possibilities for adopting less capital-intensive technologies in agriculture, but the adoption of such techniques will still be limited by the lack of a reliable water supply. Irrigation schemes involve long gestation lags and heavy

investments. Quick yielding irrigation projects like minor irrigation works and tubewells tend to be more capital intensive than large irrigation projects. As against this, it is possible to substitute capital-intensive and relatively more energy-consuming methods of plowing, sowing, and reaping used in the "modernized" agricultural sector with methods using more labor. In cattle rich countries like India, where animal dung is used as a fuel, the new price situation can give an impetus to the wider adoption of biogas plants which will provide the fuel value and also preserve the dung slurry to be used as a nutrient in place of chemical fertilizers. The benefits derivable from this seemingly simple plan are enormous. "If all the animal dung is used in biogas plants in India, about 10^{11} million m^3 of 500 BTU/Scft gas can be generated per year, which can meet all the energy needs for cooking for the entire population and at the same time provide about 4 million tons of nitrogenous fertilizers which is about twice the nitrogenous fertilizer presently being produced from oil products [in India]" (Ramachandran and Bhatnagar).

Manufacturing Sector

The other developing countries are net importers of manufactures. Over 70% of the net trade deficit of the developing countries is accounted for by the deficits in the trade in manufactures. Of these, the higher income other developing countries are more dependent on manufactured imports. However, the developing countries can make attempts towards taking up more industrial activity to bridge their trade gap. On the one side, efforts will be made to increase the value added in their exports by taking up more intensive processing of the raw material before exports. On the other side, efforts will be made to try to replace imports of fully finished manufactures by semifinished manufactures, like bulk (unpacked) chemicals, machinery in semi-knocked-down condition, etc., as these "final touches" stage of manufacture is relatively more labor intensive.

Impact on Employment

It is tempting to take the simplistic view that because of the increase in the price of energy, more labor-intensive technologies will be adopted in the developing countries and consequently employment opportunities will increase. The facts are likely to be a little more complicated. The impact on employment will depend on the capital-labor ratio of the new investment compared with such ratios in the sectors from which the investment funds are diverted to new opportunities. Except in the limited opportunities available in the rural sector like adopting labor-intensive techniques, the other options are relatively more capital intensive than other sectors and the net employment opportunities will be less than what they would have been in the absence of price increases.

Conclusion

Given these domestic adjustment possibilities, what choices are likely to be made? Determination of this is difficult; the examination so far points out that any adjustment would mean a reduction in consumption. Changes made in the investment patterns would involve opting in favor of higher capital-output and capital-labor ratios. These may have serious income distribution effects. Further, the different options involve varying impacts on different sections of the community, e.g., drawing away funds committed to the production of synthetic fibers to make investment in nuclear energy production would affect the consumption of certain classes while applying the same funds to biogas plant construction would affect certain other classes. It is therefore not merely the resource endowments and technological options that will make the decisions; the ultimate choice of the set of domestic adjustments will depend on the power structure and the political system of each country and will involve value judgments and political choices.

Therefore, it is difficult to classify the countries on the basis of income groups or resource endowments for forecasting the likely adjustments in different countries. Within each country, there will be long debates before the ultimate choices are made. Economists will spend years building their elegant models and scientists will toy with grandiose schemes for the development of new energy sources, but in the meantime the reduction in consumption has to be apportioned among the different classes of people by politicians within the limited time scale available to them, if there is no flow of compensating funds in the near future. Many nations will not have the requi-

site time to pause to plan the optimal choices in domestic adjustments, and some inefficiencies may arise. It is also possible that the violent impact of the changed relative prices will force many countries to choose options that they should have implemented even before the increase of commodity prices. In any case, a reduction in the level of welfare is unavoidable for these countries. The basic thrust of international effort and domestic adjustments should be to ensure that these reductions are not greater than they need to be.

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Appendix

Table 1. Categories of Developing Countries

	Population (in millions), 1970	Per Capita Income, 1970
Oil-exporting countries		
Algeria	14.33	$ 259[a]
Colombia	21.12	366
Egypt	33.33	200
Gabon	0.50	468
Indonesia	117.89	93
Iran	28.66	341
Iraq	9.44	278[a]
Kuwait	0.76	3148
Libyan Arab Republic	1.94	1450
Nigeria	55.07	83[a]
Saudi Arabia	7.97	344[b]
Syrian Arab Republic	6.25	258
Tunisia	5.14	248
Venezuela	10.40	854
Non-oil-exporting countries		
Higher-level income (per capita income above $340)		
Argentina	23.21	$1000
Brazil	93.39	368
Chile	8.86	614
Hong Kong	3.96	444[c]
Lebanon	2.79	521
Mexico	49.09	653
Singapore	2.07	918
Turkey	35.23	352
Uruguay	2.89	787
Medium-level income (per capita income between $200 and $340)		
Bolivia	4.93	$ 202
Dominican Republic	4.06	334
Ecuador	6.09	250
El Salvador	3.53	274
Ghana	8.64	238
Guatemala	5.28	337
Honduras	2.58	256
Ivory Coast	4.31	321
Jordan	2.31	273
Korea, Republic of	31.02	245
Malaysia	10.40	329
Morocco	15.52	212
Paraguay	2.39	230
Peru	13.59	293
Philippines	36.85	228
Senegal	3.93	201
Vietnam, Republic of	18.33	232
Zambia	4.18	335
Lower-level income (per capita income below $200)		
Afghanistan	17.09	$ 83
Angola	5.58	154[c]
Burma	27.58	68[a]
Cameroon	5.84	166
Cuba	8.47	—
Ethiopia	24.63	71
India	539.86	88[a]
Kenya	11.23	131
Khemer, Republic	6.75	117[c]
Madagascar	6.75	126
Mali	5.05	50[a]
Mozambique	7.86	145[c]
Pakistan	114.18	116[a]
Sri Lanka	12.51	161
Sudan	15.70	109
Thailand	34.38	169
Uganda, Republic of	9.81	127
United Republic of Tanzania	13.27	94
Upper Volta	5.38	57[b]
Yemen, Democratic	7.21[d]	96
Zaire	21.57	87

Source: United Nations (1972, 1973).

Note: Countries in higher- and medium-level income groups include all non-oil-exporting countries with a population of over two million and countries in lower level income groups include all non-oil-exporting countries with a population of over five million.

[a] Data relates to the year 1969.

[b] Data relates to the year 1968.

[c] Data relates to the year 1963.

[d] Population of Yemen and Yemen Democratic.

Table 2. Value of Exports and Imports of Selected Developing Countries: 1970 in 1970 Prices

(In millions of U.S. dollars)

	Oil	Other Raw Materials	Manufactures and Others	Total
Exports				
Per capita income:				
Above $340	420.5	6162.3	5422.6	12005.4
$200–$340	198.9	5039.8	3125.0	8363.7
Below $200	245.3	5141.4	2576.3	7963.0
Total	864.7	16343.5	11123.9	28332.1
Imports				
Per capita income:				
Above $340	988.2	3206.2	10946.1	15140.5
$200–$340	658.4	2279.3	6071.4	9009.1
Below $200	797.1	1990.2	6565.1	9352.4
Total	2443.7	7475.7	23582.6	33502.0
Trade balance				
Per capita income:				
Above $340	−567.7	2956.1	−5523.5	−3135.1
$200–$340	−459.5	2760.5	−2946.4	−645.4
Below $200	−551.8	3151.2	−3988.8	−1389.4
Total	−1579.0	8867.8	−12458.7	−5169.9

Source: United Nations (1970–71).

Table 3. Value of Exports and Imports of Selected Developing Countries: 1970 in 1974 Prices

(In millions of U.S. dollars)

	Oil	Other Raw Materials	Manufactures and Others	Total
Exports				
Per capita income:				
Above $340	2434.0	11908.4	7682.7	22025.1
$200–$340	1151.3	9739.2	4427.5	15318.0
Below $200	1419.9	9935.6	3650.1	15005.6
Total	5005.2	31583.2	15760.3	52348.7
Imports				
Per capita income:				
Above $340	5717.3	7022.6	14854.0	27593.9
$200–$340	3809.3	4992.4	8239.0	17040.7
Below $200	4611.7	4659.2	8908.9	17879.8
Total	14138.3	16674.2	32001.9	62514.4
Trade balance				
Per capita income:				
Above $340	−3283.3	4885.8	−7171.3	−5568.8
$200–$340	−2658.0	4746.8	−3811.5	−1722.7
Below $200	−3191.8	5276.4	−5258.8	−2874.2
Total	−9133.1	14909.0	−16241.6	−10165.7

Source: United Nations (General Assembly, 1970–71).

Discussion

Emery N. Castle

The Summer 1974 issue of *Daedalus,* devoted to a discussion of "Science and Its Public: The Changing Relationship," carries an article by Marc J. Roberts in which he says:

> In some few areas of study—particle physics, for example—it has proved fruitful for scientists to adopt the stance that the mapping from concepts to reality should be exact and complete. A "theory" is seen as a detailed blueprint of phenomena. Any lack of correspondence between concept and data is an anomaly, warranting serious research. At the other end of the spectrum, in engineering, meteorology, and most social sciences, the conceptual system of a science is but a simplified model or even just a crude sketch. Such formulations capture some of the features of the world and not others; they function primarily as heuristic and didactic devices to aid specific investigations of a statistical or case-study sort. Of course much variety is possible in the adequacy even of crude models.
>
> When concepts are stylized and inaccurate, the ability to explain/predict/control real events requires a large component of nonconceptualized "tacit" knowledge, as Polanyi has argued. While we cannot fully formulate and write down what we know by means of such "skills" or "insights," such knowledge can be reliable and perfectable; in fact, it comprises much of what we know about the world. The distinction between science and craft is thus a matter of degree. In varying combinations, both tacit and conceptual components enter into all the activities we group under either heading. And almost all transmit the "craft" aspects of their knowledge via the traditional apprenticeship pattern. Of course, exact comprehensive theories are preferable to inexact, impressionistic models. But if the best theory available is only impressionistic, then one must use it. (P. 51)

There may not have been another session in this entire meeting that illustrates so graphically the difficulty of exact mapping from concept to reality in economics. The papers we have heard involve the application of both micro- and macroconcepts within nations as well as across national boundaries. One is grateful for people who are at once knowledgeable about the conceptual base of economics and who also have great "tacit" wisdom about the complex international problems of energy, agriculture, and resources. This discussion has no great quarrel with any of the papers and will not attempt to force one.

The division of labor that has been agreed to by Raymond Mikesell and myself, and approved by our chairman, results in my discussing in greatest depth the paper by C. Peter Timmer. I will make some few comments on the paper by T. L. Sankar. It is my understanding that Mikesell will discuss both the Stern and Tims paper as well as the one by Sankar. In my remarks, I will give particular attention to the issues of energy and agriculture.

One additional introductory remark appears necessary. In common with all of the papers, I have assumed an interdependence among the developing and relatively more developed societies. Under these circumstances, to discuss the problems of the developing societies, one must take the more developed societies into account. While I will try to be clear with respect to which I am discussing, I do not justify including the more affluent societies in the discussion beyond noting interdependence at the outset.

The Timmer paper impresses me as a competent treatment of a model which is useful in understanding the basic economic components of global food-energy relationships. The model is not interpreted mechanically but rather is given maximum economic extension in several directions. As a consequence, Timmer has surely reached the maximum physical product on his production function in the use of this model. Further extensions may well result in negative marginal returns unless the assumptions of the model are relaxed or unless the model, as formulated, is buttressed by greater treatment of the empirical magnitudes involved.

An inevitable consequence of reducing so much complexity to a simple model is the loss of detail. In his excellent paper, Sankar provides some of this detail. For example, he notes that countries may adjust to trade deficits in a variety of ways which may have

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This paper was presented in a session entitled "Recent Resource Problems of Less Developed Countries."

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very different effects on consumption. Consumption may be reduced in the immediate future, a reduction in consumption may be postponed, or the reduction may be spread over a longer period of time. Levels of living around the world and especially in the more affluent societies are heavily dependent on intensive energy usage. These levels of living will be reduced with reluctance. Sankar implies that political considerations will tend to favor consumption over production policies which, in turn, may influence whether agriculture will be able to compete for scarce fuel supplies. Most governments will recognize the importance of food per se and will provide for energy for the on-farm sector. The more advanced the agriculture of a nation, the greater the energy use by agriculture in off-farm activity, that is, the purchased inputs of machinery, fertilizer, and chemicals represent a significant energy requirement and these may not be provided for by policies which favor on-farm production and consumer goods.

Another detail that Timmer was unable to incorporate in his model pertains to the distinction between the food in the aggregate, which includes marketing services as well as agricultural products at the farm level. In the United States, on-farm use of energy is probably in the neighborhood of 2% to 3% of total usage. The agricultural input industries may increase this to as much as 5%. But this probably is more than doubled if one includes the processing, transporting, and merchandising of food products. Our understanding of the total situation will be enhanced by utilizing two economic concepts. One is the income elasticity of demand for food as contrasted to the income elasticity of demand for marketing services. We will need to utilize this concept to understand differences in the composition, as well as the quality, of agricultural output among countries with different income levels. The other is the possible difference in market power among the various production and marketing functions. It may not be the case that "only the commercial farmer is fully protected on the income side." Timmer's inference seems to be that high food prices will be sufficient to insure the profitability of commercial agriculture and bring forth additional agricultural production. This will be true only if the control of the strategic factors of food production and marketing are with the commercial farmer. Recent divergence in retail and on-farm price trends for a number of agricultural commodities gives some cause for concern in this respect.

We are indebted to Timmer for his introductory comments on the necessity for energy-intensive agriculture to meet world food needs and for correctly stressing the role of social institutions in this context. We are currently witnessing a rash of statements on energy efficiency and "net energy" that have already done mischief and have the potential of doing much more. The reduction of all energy to a common denominator such as BTUs overlooks the differing capacity of varying energy sources to serve the interests of mankind. Economists have a most important communication problem both with the public generally as well as with policy makers. Energy relationships themselves as well as the relation of energy to economic incentives become basic to this discussion.

Finally, two issues are identified that are fundamental to the resource problems of the developing societies. Both transcend national boundaries and both may confound our attempts to map from conceptual blueprint to reality. One relates to the production function for food and energy and the other to control of the strategic factors of production.

It is redundant, obvious, and verges on the tautological to say that the advances in material progress in the past 200 years have resulted in energy-intensive societies around the world. Both production and consumption processes embody the use of energy in a wide variety of forms. Under these circumstances, it will be exceedingly difficult for economists to specify appropriately all of the relevant production and consumption functions with explicit energy components. This state of affairs could bias energy consumption estimates either upward or downward. On the one hand, it suggests there are countless ways in which production and consumption processes can be changed that will substitute other inputs for energy, although I agree with the papers that labor is not likely to be one of the inputs which will be substituted to any significant extent. But, on the other hand, the pervasive nature of energy increases the possibility of overlooking the energy embodied in various goods that are substituted for direct energy use. This hidden or embodied energy may tend to bias our estimates downward. Even so, for the more developed societies, there is considerable variation in energy consumption per capita among countries with essentially the same per

capita income. On balance, then, I am inclined to agree with Paul McCraken that the aggregate impact of a more realistic pricing policy is likely to be very substantial.

The other issue pertains to the control of strategic factors of production within countries in a period of rapid change in resource availability. The papers we have had at this session have given us much insight into the changing terms of trade between countries. Particular attention has been given to food and oil because of their strategic importance on a global basis. We should not lose sight of the fact, however, that resource availability is also changing within the countries as a result. How these changes will affect the distribution of control over the most strategic factors of production is unknown at this time. For that reason, it will be difficult to make future predictions with respect to the distribution of income resulting from these changing conditions of resource availability both in the developing countries and elsewhere. I end with a plea that we not lose sight of the distribution of income as an area of research, not in an accounting or mechanical sense but rather by an attempt to anticipate who will control strategic factors of production within a country and who will then be in a position to command greater returns to those factors. Such knowledge, I submit, will be crucial to an understanding of supply response.

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Discussion

Raymond F. Mikesell

The paper on "The Relative Bargaining Strengths of the Developing Countries" is the most comprehensive treatment that I have heard of the currently popular question of whether there are more OPEC-like cartels in our future. The answer given by the authors is generally optimistic from the standpoint of those in the industrial countries who have been worrying about the problem. However, the prescription for a successful commodity cartel in this paper as well as in the literature generally is somewhat ambiguous. I have often thought it would be useful to have a general theory of producer country cartels that would bring together the various explanatory variables such as market shares, substitutability, demand and supply elasticities, and the export dependence, financial strength, and cohesiveness of the cartel members for the determination of some index of monopoly power. But I doubt whether the model could be tested satisfactorily. Although there are commodities whose production and marketing share many of the characteristics of OPEC's oil, such as concentration of production and marketing structure, none approach oil in terms of the following three characteristics: (*a*) universal essentiality, (*b*) lack of readily available substitutes, and (*c*) the capacity of a few large producers to restrict output without impairing their import capacity or national economic welfare. In fact, given the rate of increase in world demand before 1973, Saudi Arabia alone accounted for half of the required annual increment of petroleum output (McKie). In the short run at least, Saudi Arabia could operate on the inelastic portion of the demand curve for her own oil without any collaboration from the other producers.

One of the factors contributing to the bargaining power of the OPEC cartel is the vertical integration of the petroleum industry. OPEC members have been able to use the marketing facilities of the international companies producing the oil and increase government revenues by raising taxes which the petroleum companies pass on to the ultimate consumers. Now that a large portion of the OPEC members' producing facilities are being nationalized, the question has been raised as to whether the companies will continue to serve as the tax collectors for the OPEC governments or whether M. A. Adelman's (1974, 1972) dream of nationalized enterprises fiercely competing with one another for shares in the world market and driving down the price of oil toward its marginal cost of 20¢ a barrel is to be realized. Unfortunately, this scenario does not seem to be evolving. International companies are to remain as the distribution channels, buying the oil at prices dictated by the cartel and providing their productive services for a fee. This arrangement suits the companies and it is clearly desired by the OPEC members who would not relish being put in the position of competing with one another on a price basis for a share of the world's oil market. The companies will continue to validate the cartel. I am not suggesting that petroleum prices would decline if the OPEC governments were forced to sell their petroleum in an open world market, at least not immediately. However, under these circumstances, the temptation of members like Iran to shave prices in order to expand sales would be very great and the cartel would become increasingly vulnerable as supply increased relative to demand.

A relevant question is whether vertical integration in other commodities increases the bargaining power of producer associations or cartels. There is some evidence that it does. It is easier to get an agreement among governments to increase taxes on output marketed by a vertically integrated firm than it is to get them to agree to maintain prices on a product which they must sell on the world market. For this reason the bauxite producers are likely to be more successful in raising government revenues than will the members of CIPEC (Intergovernmental Council of Copper Exporting Countries) in maintaining or raising copper prices. Nevertheless, as Stern and Tims have shown in their review of the Panama agreement on bananas, there are other factors that

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may limit the ability of producer associations to control prices by the tax method in an integrated industry.

I quite agree with the assessment of the authors that the overall bargaining strength of the non-oil developing countries is not great, even though they appear better able to enter into collusive arrangements regarding the export of particular commodities than do the developed countries in mobilizing their countervailing power. The potential bargaining strength of the developed countries even for dealing with the OPEC cartel is truly enormous, but Sheik Yamani is not losing any sleep over the possibility of the industrialized nations being able to agree on a common program for exercising this potential power.

The issue of the bargaining strength of the producers of raw materials has important implications for the formulation of fair trading rules in the GATT. The U.S. Congress rejected the International Trade Organization negotiated in the early postwar period partly on the grounds that it sanctioned and provided machinery for the negotiation of commodity stabilization agreements, and the U.S. government has been ambivalent regarding commodity agreements throughout the postwar period. Economic arguments for and against commodity agreements are well known and most economists tend to put more faith in free markets than in administered prices. Yet we seem to be moving rapidly in the direction of collusive agreements among producing countries that may prove harmful to the welfare of both producers and consumers or to world economic welfare generally. The United States would undoubtedly like to see a strong GATT provision outlawing administrative measures to restrict exports, but the developing countries are unlikely to agree to or honor such a commitment. Perhaps the only feasible course is to give serious consideration to internationally supervised commodity agreements as a second-best solution, however abhorrent they may be to those of us who remain faithful to the self-correcting role of the free market.

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The Economics of Outer Continental Shelf Leasing

Robert J. Kalter, Thomas H. Stevens, and Oren A. Bloom

An analytical framework of the Outer Continental Shelf lands petroleum investment and production decision process is developed and utilized to evaluate public resource leasing policy alternatives. The impacts of alternative lease systems upon rates of production, investment levels, total resource recovery, and government revenue are presented and discussed. Trade-offs implicit in various leasing strategies and the geophysical-institutional-engineering-economic interactions which must be accounted for in public resource management are pointed out. Possible modifications in the current institutional system are suggested.

Key words: energy policy, leasing, petroleum supply.

Recent world events have highlighted the growing dependence of the United States on imported crude oil and petroleum products. To illustrate, the portion of petroleum to gross energy consumed (on a BTU basis) in the United States has increased from 34% in 1947 to 46% in 1973, while crude oil and petroleum product imports increased from 3% to 17% of this total over the same time period. Domestic production of crude oil, on the other hand, began a decline in 1973 and this decline has continued at an accelerated rate through the first quarter of 1974 (U.S. Department of the Interior, 1974).

Although scarcity of proven domestic petroleum reserves is a contributing factor to potential energy problems, economic, technical, institutional, and political factors have influenced the rate of new discoveries. With the depletion of proven petroleum deposits located on land, governmental policy with respect to energy resource leasing on federal lands has been and will continue to be a key factor guiding private market forces. Of particular importance are the potential petroleum reserves located offshore on our Outer Continental Shelf (OCS). Although leasing of such acreage has been underway for over twenty years, less than 5% of the acreage available for lease has been opened for bid. Moreover, it is estimated that approximately 50% of our domestic oil and gas resources are located on the OCS (U.S. Senate 1974). Recognition of this fact and of the potential importance of this policy variable to future domestic petroleum discoveries and production has led to a rapid change in governmental policy since 1973. Presidential directives have been taken which would increase the annual offshore acreage leased for exploration from 1 million acres per year in 1972 to 10 million acres per year in 1975.

Regardless of the annual lease sale size, however, the resulting market effects will depend upon the geophysical aspects of the acreage leased and associated public policies which are adopted. The former, which can be partially influenced by the schedule and location of potential lease sales, determines the amount of oil in place available for discovery. For unexplored or "wildcat" areas, petroleum geologists make an educated guess about the amount of oil in place (Cram). Given any stipulated amount of potential petroleum reserves, however, other public policies can have a major influence on the timing of oil production, the amount of ultimate recovery, and the magnitude of governmental revenue collected through the bidding and production royalty system. Continued controversy has surrounded the public discussion of policies

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related to such issues. Included in such discussions have been questions related to the appropriate lease term options (such as bonus bidding, royalty bidding, or profit sharing plans), the effect of various taxation policies (such as the oil depletion allowance), and the role of governmental actions affecting market prices for petroleum (Corrigan).

In this paper, we set forth a theoretical framework which is designed to encompass the elements of expected market behavior when public lands are offered for lease to the private sector. The framework outlined includes a consideration of basic economic elements as well as the interrelationships between such elements and the geophysical and engineering aspects of any petroleum extraction process. In addition, taxation policies and the role of uncertainty are incorporated. The resulting analytical model is calibrated and verified with historical data and then utilized to evaluate relevant leasing policy alternatives. Included are an analysis of the rate and timing of petroleum production, estimates of governmental revenue, and investment requirements for the various alternatives, as these factors relate to potential petroleum reserves of a given magnitude.

Analytical Framework

In recent years several economic models of the petroleum investment and production decision process have been developed (Adelman; Baughman; Bradley; MacAvoy and Pindyck; National Petroleum Council). However, none are directly applicable to the analysis of alternative leasing strategies. Moreover, previous formulations have often failed to consider the interface between economic and engineering phenomena relevant to such decisions. For example, with few exceptions, the dependence of recoverable reserves upon the rate of production is ignored (Kuller and Cummings). More importantly, possible control of production decline rates, within reasonable limits, by petroleum producers is generally not recognized by empirical studies (VanMeurs). Finally, important economic considerations, such as risk and taxation, are seldom accounted for in a comprehensive manner.

The analytical framework presented here incorporates the above factors in a model of aggregate private market response to public energy leasing strategies. Engineering and economic considerations are included so that a wide range of public policy alternatives, as well as physical phenomena, related to petroleum production and investment decisions may be quantitatively examined.

The framework is based upon the assumption that a known probability distribution of the size and location of original oil in place, R, exists such that the expected value and variance of R in any given area may be estimated (Allais; Uhler and Bradley). The total resource or production constraint can then be represented by

$$xR \geq \int_0^T q(t)dt, \tag{1}$$

where R represents original oil in place, x a percentage indicating the maximum oil in place that is physically recoverable given current technology, T the production time horizon, and $q(t)$ the rate of production. Theoretically, when public lands are offered for lease, an optimum is obtained by the private sector through maximization of net present value revenue subject to this constraint (Kuller and Cummings). The complexity of this optimization problem is largely due to the unknown function $q(t)$. However, for the purpose of empirical analysis, the problem is simplified if $q(t)$ is expressed as a function of the initial capacity installed and the production decline rate such that

$$q(t) = q_0 e^{-at}, \tag{2}$$

where q_0 represents initial installed capacity, and a represents the rate of decline in production (Adelman; Arps; Baughman).[1] This relationship is based upon the premise that as petroleum is extracted, natural or artificial reservoir pressure is reduced so that production declines through time at the rate a (Kuller and Cummings; McDonald 1967).

The rate of pressure reduction, and hence production decline, is a direct function of a number of geological factors including the permeability and porosity of the strata. Of greater importance, however, is that natural or artificial pressure decline may be partially controlled by producer selection of appropriate completion technology and operating

[1] Both of these variables are assumed to be subject, within limits, to producer control as is the production time horizon. Depending upon the physical characteristics of the petroleum province and the specific technology utilized, alternative function forms may be specified (Arps; U.S. Department of the Interior officials).

procedures (Kuller and Cummings; U.S. Department of the Interior officials). This control is of particular importance since resource recovery is generally a negative function of the rate of production (Davidson; Kuller and Cummings; McDonald 1967). For the purpose of exposition, it is postulated that recovered reserves, R_o, may be expressed as

$$(3) \qquad R_o = xR - \beta q_o e^{-a},$$

where β is a physical parameter related to geological conditions and $q_o e^{-a}$ the initial rate of production.[2] The cumulative output may then be written as

$$(4) \qquad R_o = \int_0^T q_o e^{-at} dt,$$

where R_o equals $xR - \beta q_o e^{-a}$ from equation (3). For a given production time horizon, equation (4) states that cumulative output is equal to the magnitude of reserves which may be recovered at a given rate of production. In the subsequent analysis, this assumption is applied over all alternative bid systems.

Given R, a projection of the optimum level of investment or initial capacity, q_o, the production decline rate, a, and the production time horizon, T, must be made by a potential lessee before determining his bid. Economic theory indicates that this projection will be based on the maximization of after-tax net present value revenue (Solow). For the purposes of leasing policy analysis, relevant cost components entering the after-tax net revenue calculation include investment cost (which can be defined as a direct function of the capacity installed), operating costs, royalties, the depletion allowance, the deduction for intangible drilling and development expenses, and other relevant tax provisions.[3] After-tax net revenue taken over the anticipated production period and discounted then equals the anticipated economic rent for the resource on a present value basis.

The theoretical framework can be expressed in the form of two basic relationships. The first defines the production time horizon limit as a function of physical, as well as economic, parameters. Theoretically, this limit is obtained when current expenses per unit equal revenue per unit of output. This relationship may be written as

$$(5) \qquad [(P_o + P_1 t)(1 - \lambda) - K_o e^{(\theta + a)t}] - \phi[(P_o + P_1 t)(1 - \lambda) - z(P_o + P_1 t)(1 - \lambda) - K_o e^{(\theta + a)t}] = 0,$$

where P_o represents initial price per unit of production, P_1 the annual anticipated change in unit price, λ the royalty rate, ϕ the corporate income tax rate, z the percentage depletion allowance, K_o the initial operating costs per unit of capacity, and θ the physical parameter related to initial reservoir conditions.[4] The first portion of the relationship represents net per unit revenue before taxes in time, t, while the last part represents taxes payable per unit.

The second relationship maximizes after-tax net present value revenue subject to the production time horizon constraint represented by equation (5). For the purpose of exposition this function is written in two parts. The first part, which represents net present value revenue before taxes ($NPVBT$), is expressed as

$$(6) \quad NPVBT = \left[q_o \int_0^T (1 - \lambda)(P_o + P_1 t)e^{-(a+r)t} dt\right] - \left[q_o \int_0^T K_o e^{[\theta - r]t} dt\right] - bq_o,$$

where q_o equals $axR/(1 - e^{-aT} + \beta a e^{-a})$ from equations (3) and (4), b the investment cost per unit, and r the discount rate. Thus, the first term on the right side of equation (6) represents the present value of gross revenues less royalty payments. The second term represents the present value of operating costs and the last term represents investment.

The present value of taxes payable (TAX) may be expressed as

[2] Recovered reserves are expressed as a linear function of the rate of production since, for any given set of geological conditions which determine the value of β, the faster the rate of production, the lower the volume of petroleum that is recovered. This results because reservoir pressure is inefficiently utilized at high rates of production. Although the form of this relationship has been the subject of substantial debate, the concept is often ignored in empirical studies (Davidson; Kuller and Cummings; McDonald 1967). The specific functional form presented is utilized solely for simplicity of exposition.

[3] In certain applications, investment cost may also be expressed as a function of reserves to account for economies of scale. For a discussion of taxation see Kahn; McDonald 1967; U.S. Senate 1974.

[4] Since total operating costs increase by the value θ through time, but remain constant in any time period regardless of the decline rate, unit costs increase at an exponential rate as production declines through time. This phenomenon is due to equipment obsolescence as well as increasing utilization of secondary recovery techniques (Arps; Davidson; U.S. Department of the Interior officials). In notation form, total operating costs in any time, t, are expressed as $q_o K_o e^{\theta t}$. Thus, unit costs become

$$\frac{q_o K_o e^{\theta t}}{q_o e^{-at}} = K_o e^{(\theta + a)t}.$$

(7) $TAX =$

$$q_o\phi \left\{ \int_o^T (1 - \lambda)(P_o + P_1 t)e^{-(a+r)t}dt - \int_o^T K_o e^{[\theta - r]t}dt - \left[\sum_{i=1}^{n} \left[\frac{n - i}{(n^2 + n)/2(1 + r)^i} \right] [yb(1 - \alpha)] \right] - z \int_o^T (1 - \lambda)(P_o + P_1 t)e^{-(a+r)t}dt - (1 - y)b \right\} - \Omega q_o b,$$

where ϕ represents the tax rate, n the time horizon for depreciation, z the depletion rate, y the percent investment which is tangible, α the percent investment salvageable at n, and Ω the investment tax credit rate.[5] On the right side of equation (7), the first term in brackets represents present value tax deduction for depreciation, followed by deductions for the depletion allowance, intangible drilling expenses, and the investment tax credit. When these per unit values are subtracted from the per unit present value revenue before taxes and the result multiplied by the present barrel equivalent of production and the corporate income tax rate, total taxes payable can be calculated. Equations (6) and (7) may then be combined and salvage value is added to obtain after-tax net present value.[6]

For implementation, the framework may be restated such that after-tax net present value revenue is maximized subject to the cumulative production and time horizon constraints set forth in equations (4) and (5).[7] The solution is then accomplished through the use of a computerized constrained search algorithm. This algorithm iterates the decline rate, a, over an exogenously specified range for the time horizon, T, subject to the upper limit time constraint specified in equation (5). Products of the solution are the optimum decline rate, a^*; the optimum time horizon, T^*, which may be less than the constraint calculated in equation (5); the optimum initial capacity, q^*_o; annual production; cumulative production; and the present value of after-tax revenue. By manipulation of the latter value, various bidding options can be simulated. For example, under a bonus bid system, the expected bid plus royalties should equal present value of the economic rent given pure competition and the expected value of R. Under a royalty bid system, cumulative royalty payments equal the anticipated economic rent. Thus, after-tax net present value revenue can be constrained to zero with the royalty rate, λ, being determined.

The previous discussion points out several issues which have obvious policy implications. First, the economic rent is directly related to the expected level of reserves. This factor is in turn a function of the schedule and location of lease sales. Second, the royalty rate, production rate restrictions (based on maximum efficient rate regulations), tax policy, and government policy affecting market prices are all important factors affecting petroleum production and investment decisions. Third, producer control over production decline rates and initial investment levels are important determinants of production profiles and government revenues under alternative resource allocation systems.

Policy Evaluation

The framework set forth above was calibrated and tested using historical data. Unpublished governmental statistics of oil reserves and development-operating costs, along with engineering estimates of physical parameters, for recent lease sale areas in the Gulf of Mexico were utilized. A complete *ex post* analysis is not yet possible, since the production phase is in the early stages for most of these areas. All resulting bid estimates, however, were within 10% of actual values and other independent variables were reasonable and consistent with current experience in the Gulf (U.S.

[5] The sum-of-the-years' digits depreciation method is used. Tax treatment of bonuses is ignored. This omission is consistent with the industry decision process and does not substantially alter the empirical results (U.S. Department of the Interior officials).

[6] For model implementation, taxes payable are calculated separately for the first year and, then, for the remaining production time horizon. As mandated by statute, the depletion deduction is limited to 50% of net income before depletion. First-year tax deductions in excess of those that can be utilized against lease revenue are assumed to be applied against gross revenue and/or taxes (as the case may be) on other company operations (with the exception of percentage depletion which cannot be used in this manner). In essence, these excess tax write-offs are credited as additions to the after-tax net present value of the lease. For simplicity, a one-year lease development schedule was assumed. Consequently, given tax legislation, excess tax write-offs only accrue in the first year. This assumption provides a consistent and reasonable basis for comparing policy alternatives.

[7] Two assumptions are implicit. First, unitization is imposed so that externalities associated with the private exploration of common property resources may be ignored (McDonald 1971). Second, user or opportunity costs associated with resource exhaustion in the pure Ricardian sense are not incorporated.

Department of the Interior officials; U.S. Department of the Interior 1970, 1972).[8]

Given an acceptable degree of accuracy in the *ex post* application of the analytical framework, we now turn to an evaluation of public leasing policy alternatives which have been widely suggested as superior to the current bonus system (Corrigan). These include a bonus system with an increase in the fixed royalty rate, a royalty bid system, a profit share system, and the elimination of the depletion allowance. The first two alternatives have been advocated as a means of reducing the initial cash bonus to encourage exploration by small independent producers. It is also argued that such systems may result in increased government revenue. On the other hand, a royalty based resource allocation method may lead to inefficient production decisions, as well as increased administrative costs. Theoretically, such inefficiencies might be avoided through the implementation of a profit share resource allocation system. However, in the long run, this system could lead to a misallocation of resources among industries. Finally, continued controversy surrounds the effect of the depletion allowance on the rate of resource development, economic rents, and allocative efficiency (Kahn; McDonald 1961).

The various systems were analyzed by assuming that offshore acreage located in less than 300 feet of water and containing an estimated 1.5 billion barrels of recoverable oil in place were being offered for lease. Assumptions regarding product prices, costs, tax structure, and physical parameters are identical to those used for the recent MAFLA (Mississippi, Alabama, Florida) sale evaluation (see footnotes 6 and 8). Table 1 displays the results of model runs on the various scenarios.

As shown in table 1, an increase in the fixed

[8] An an example, the MAFLA (Mississippi, Alabama, Florida) sale in 1973 consisted of 146 lease tracts and brought forth bonus bids of $1,491,065,230 ("Mafla-sale bids"). Of course no production has taken place on this acreage to date. However, using an $8.00 per barrel oil price, the model calculated a total bid of $1,570,000,000. The results assumed current tax legislation, a 10% discount rate, an $0.08 per year price increase for oil and costs estimates relevant to the forecast structures and water depths of the sale area (U.S. Department of the Interior 1970). Forecast initial capacity installed was 1.07 × 10[8] barrels with a decline rate of 1% and cumulative production of 0.139 × 10[10] barrels.

Table 1. Impact of Alternative Policies

Impact Categories	Unit[a]	Current Bonus Bid System	Increase in Fixed Royalty	Royalty Bid	Elimination of Depletion Allowance	Profit Share System[b]	Profit Share System[c]
Royalty rate, λ	%	16⅔	50	54	16⅔	16⅔	16⅔
Profit share rate	%	0	0	0	0	27[d]	27[d]
Time horizon, T^*	Yr.	14.0	24.0	28.0	15.0	14.0	18.0
Initial capacity, q_o	MMBBL/Yr.	106.73	67.18	59.03	100.54	106.73	85.90
Production decline rate, a	%	1	1	1	1	1	1
Investment	$	2.67	1.68	1.48	2.51	2.67	2.15
Total recovery, R_o	MMBBL	1394.3	1433.5	1441.6	1400.5	1394.3	1415.0
Royalty	$	1.03	2.43	2.38	1.00	1.03	0.91
Bonus bid	$	1.57	0.19	0	1.12	1.14	0.47
Taxes paid	$	0.57	0	0	1.02	1.00	1.61
Total government revenue	$	3.17	2.62	2.38	3.14	3.17	2.99

[a] All monetary values are present values (discounted at 10%) in billion dollars. MMBBL signifies million barrels.
[b] Income base includes the depletion deduction.
[c] Income base excludes the depletion deduction.
[d] For purposes of illustration, a 27% rate applied to the respective taxable income bases was used. Thus, a corporate tax rate of 75% results.

royalty rate to 50% and a royalty bid system both lead to a reduction in investment and initial capacity installed as compared to the current system.[9] At the same time, the production rate is reduced which results in an increase in recovery (or cumulative production) as well as a longer production time horizon. In other words, anticipated production is lower in the first few years and higher in later periods as compared to the present system. This result, when coupled with the accelerated OCS lease sale schedule, has obvious implications for the timing and level of imports as well as balance-of-payments considerations.

Both royalty based resource allocation systems lead to a decrease in the bonus bid. However, the present value economic rent, which is traditionally defined as royalty plus bonus bid revenue, increases as the royalty rate is raised from 16% to 50%. In the cases presented, this is partially due to distortions inherent in the tax system as well as the specific tax assumptions used (see footnote 6). Given the structure specified above, the bonus bid is defined to equal after-tax net present value revenue. Thus, the bonus bid is reduced by the calculated present value of tax payments. As the royalty rate is increased, taxes payable under the assumptions specified are reduced, and may, as in the examples presented, fall to zero. Thus, the appropriate comparison under the alternative systems is the level of total government revenue. On the basis of this comparison, both royalty based resource allocation systems lead to a decrease in government revenue on a present value basis.

However, the interaction between a, q_0, and T can, under the assumption of resource recovery utilized, result in total government revenue being greater under the royalty bid systems than under cash bonus bids—see equation (4). Changes in the relationship between total recovery and the production rate and/or changes in the limits of producer control over the range of the production decline rate (because of geophysical factors) may cause such a phenomenon.[10]

Elimination of the current 22% depletion allowance also results in a reduction in the initial capacity installed as well as total investment. However, due to the alteration in the timing of production, as well as the increased taxes paid, total government revenue on a present value basis is decreased slightly over the current system. These results tend to support the hypothesis that the depletion allowance results in higher investment levels and production rates. The analysis also suggests that the depletion allowance tends to swell economic rents (Davidson; Kahn).

In the case presented, the impact of a profit share system depends largely upon the profit share base as well as the assumption regarding first-year tax deductions. For example, under the assumptions specified, if the base includes the depletion allowance, the initial capacity installed is not affected. However, a significant decrease in capacity results if the base excludes the allowance. This result may be expected since, in the former case, an increase in the profit share rate leads to an increase in the effective depletion allowance per unit of production.[11] Hence, there is an incentive to maintain investment levels.

In all cases presented, an optimum is obtained by maximizing after-tax net present value revenue, subject to the constraints representing resource availability and the production time horizon. Thus, the industry may adjust the production decline rate, the initial capacity installed, and/or the production time horizon, as the bid system changes in order to maximize net present value revenue. For example, initial capacity may fall and the time horizon may increase, as occurred when the royalty rate was increased from 16% to 50%.

This result is contrary to previous studies which are based upon the assumption of a constant production profile (U.S. Department of the Interior officials; VanMeurs). Given this assumption, any increase in the royalty rate reduces marginal revenue, and lower resource recoveries and government revenues may be obtained.[12] This approach, however, is not

[9] When left to competitive forces with no bonus bid required, the royalty rate expected as a bid under the assumptions used was 54%.

[10] Production restrictions, such as maximum efficient rate (MER) regulations, are based upon the fact that the decline rate can be altered (McDonald 1971; National Petroleum Council). Although the degree of control over this rate is a function of individual reservoir characteristics as well as the completion technology, for empirical purposes a lower bound of 1% is utilized in this analysis. Since in the cases presented, it is implicitly assumed that the value of b and/or θ is independent of the decline rate, after-tax net present value revenue is maximized at the lower bound for all systems.

[11] If a corporate profits tax rate of 75% is imposed, the after-tax value of the depletion deduction is increased from 11% to 16½% of the value of expected production.

[12] For example, if the production profile is fixed at the level calculated to prevail under the current bonus bid system, production does not occur if the royalty rate is increased to 50%.

flexible in terms of the initial capacity installed, the production time horizon, as well as the production decline rate.

Of particular importance is the range within which the production rate can be varied by petroleum producers. If that range is limited by physical conditions or institutional factors such as maximum efficient rate (MER) restrictions, net present value revenue is altered for all lease systems analyzed. Thus, the absolute level of government revenue cannot be specified a priori since it depends on the geophysical-institutional-economic interactions discussed above.

Moreover, the impact of all bid systems upon government revenue is subject to several qualifications. First, for each alternative it is assumed that a 1.5 billion barrel expected reserve will be discovered. If it turns out, *ex post,* that this value was greater than that actually discovered, royalty collections and/or profit shares would obviously be reduced whereas the bonus bid collected would remain unaltered.[13] If the value is less than the actual discovery, royalty revenues and/or profit shares would be increased. The final result with respect to government revenue depends on the level of actual reserves discovered, the relationship of the lease system to uncertainty evaluation by the industry, and the interaction between reduced revenues and the tax-royalty structure.[14] Second, lease profitability (and consequently, development feasibility) depends both upon the level of the royalty rate and product prices. For example, under a 50% fixed royalty system and a $5.00 per barrel oil price, no bids would be generated for the acreage offered under the assumptions discussed previously. However, a bonus bid would be offered at current royalty rates.[15]

[13] In addition, if actual reserves are less than expected, the field may be abandoned under a royalty bid system. For example, once lease acquisition takes place by cash bonus, it is profitable to produce (*ceteris paribus*) if actual reserves total at least 623 million barrels. However, reserves must total at least 1,258 million barrels for production to be profitable under the royalty bid system.

[14] A full evaluation of the uncertainty issue is not present here. However, the framework used does permit these factors to be incorporated. For example, under a royalty system, a prospective bidder may bid the full value of the estimated resource because relatively little cost is entailed in the event of a dry hole. On the other hand, the bonus bidder may discount his bid since the risk is higher. However, in the analysis presented, risk of an actuarial nature is assumed throughout. This assumption is based upon the premise that the investment decision is viewed as one of a large number of independent decisions. Therefore, expected value is an appropriate risk adjustment in all cases (Maass et al., pp. 137–58).

[15] Inefficiencies of this type are not associated with a pure royalty bid system.

Summary and Conclusions

In view of the fact that domestic petroleum production has dropped below 9 million barrels per day (with approximately 17 million barrels per day being consumed), the schedule and strategy for leasing federal lands containing energy resources will assume a vital role in any public policy to reduce U.S. dependence on foreign sources. It is generally agreed that, outside of Alaska, most large petroleum pools located on land have been discovered. The OCS is the largest remaining petroleum resource area available to the U.S. (National Petroleum Council). The U.S. Geological Survey estimates total potential oil and natural gas reserves from OCS areas at 65–130 billion barrels and 395–790 trillion cubic feet, respectively. However, the degree to which these projections can be converted to actual reserves and the extent of their recovery depends on more than geological phenomena.

This analysis has pointed out the trade-offs implicit in various leasing strategies and the geophysical-institutional-economic interactions which must be accounted for in making public resource management decisions. The trade-offs between the objectives of government revenue maximization, cumulative resource recovery, and the timing of production have been demonstrated for various lease systems. In general, we have shown that contingency lease arrangements tend to shift production profiles toward the future with an associated increase in resource recovery. As this occurs, public revenues may be reduced. However, the impact of the various lease systems upon government revenue is subject to several qualifications including the assumption with regard to uncertainty evaluation by the industry as well as the degree of producer control over production rates. Moreover, the level of government revenue under all systems depends upon the geophysical factors associated with individual reservoirs.

Given the current energy situation, the analysis does show a decided advantage, however, for the present cash bonus plus royalty leasing system. Production profiles, from a given leased area, are substantially shorter than under an all royalty approach. Total recovery, while somewhat lower than the royalty case, is not greatly reduced in terms of present barrel equivalents. As a result, the present value of total government revenue tends to be maximized under the cash bonus

system. As indicated above, however, this may not hold in all situations.

Elimination of the oil depletion allowance under any lease system would tend to reduce annual production and total government revenue but increase total recovery. However, a profit share system could be designed which would closely approximate annual production and total recovery from other systems by proper manipulation of the profit share rate and the associated income base. On the other hand, the long run effect might be distortions in the pattern of capital investment with subsequent feedback on the impact categories analyzed in this paper. Providing that it does not result in the erection of undue barriers to entry (because of high capital requirements and the uncertainty involved in petroleum exploration), the current cash bonus system appears to be an appropriate public vehicle for capturing economic rent and maximizing annual production from newly discovered petroleum reserves on federal lands. Elimination of the percentage depletion allowance would not greatly affect this conclusion and would, in addition, slightly increase resource recovery. Thus, removal of this tax distortion would appear warranted.

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Simulated Beef Feedlot Behavior under Alternative Water Pollution Control Rules

D. Lynn Forster

Rules are being established by federal and state agencies to control water pollution from feedlots. In order to investigate the impact of alternative rules, a simulation model was constructed to represent the behavior of beef feedlots in Michigan and similar states over the 1974–85 period. Individual firm behavior was simulated as the firm formed expectations concerning *ex ante* production relationships and input and output prices, made decisions based on these expectations, and had its success determined by *ex post* production relationships and input and output prices. Results indicate that while the alternative rules would not have severe impacts on feedlot production, their impacts would be regressive.

Key words: feedlot, water pollution control, firm growth, agricultural simulation.

Increasing concern has arisen over the environmental degradation associated with agricultural production. At the local, state, and national levels, legislative bodies and/or administrative agencies are being pressured to establish mechanisms to protect the environment. The primary instrument used to correct the level of pollution and environmental degradation has been sets of rules governing the use of inputs or the level of pollutant output. The objective of this study is to provide a methodology to investigate some of the costs involved in a set of alternative rules which attempt to control water pollution. The methodology was applied to beef feedlot production which has received attention in federal environmental legislation and subsequent federal agency rule making.

The most recent federal environmental legislation affecting feedlots was the Federal Water Pollution Control Act Amendments of 1972. This act required that the U.S. Environmental Protection Agency (EPA) establish rules for abating pollution from point sources of waste discharges.[1] Feedlots were specifically included as a category of point sources making them subject to the National Pollution Discharge Elimination System (NPDES) (U.S. Congress). All feedlots identified by EPA as being subject to NPDES were subjected to a permit program which required a two-step reduction in the allowable rate of pollution discharge. The first step, to be achieved by July 1, 1977, is to be accomplished by the employment of the "best practicable technology currently available." This technology for beef feedlots has been identified by EPA as the control of the runoff from a ten-year, twenty-four hour rainfall event plus all process generated wastewater. The second step, to be achieved by July 1, 1983, is to be accomplished by the employment of the "best technology economically achievable." For beef feedlots, this requirement has been translated by EPA as the control of the runoff from a twenty-five year, twenty-four hour rainfall event plus process generated wastewater.[2] To date, these requirements have been applied to those beef feedlots with greater than 1000-head capacity. The federal EPA is in the process of studying

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[1] Point sources are any "discernible, confined and discrete conveyance . . . from which pollutants may be discharged" (U.S. Congress, p. 72).

[2] Process generated wastewater is defined as "water directly or indirectly used in the operation of a feedlot . . . spillage or overflow from animal or poultry watering systems; washing, cleaning or flushing pens, barns, manure pits or other feedlot facilities. . . ." Process generated wastewater is near zero for most beef feedlots. The terms ten-year, twenty-four hour rainfall event and twenty-five year, twenty-four hour rainfall event mean "a rainfall event with a probable recurrence interval of once in ten years or twenty-five years as defined by the National Weather Service" (Office of the Federal Register, p. 5708).

the economic impacts of extending these provisions to feedlots of less than 1000-head capacity.

States may also have a role in determining the level of pollution abatement. The appropriate state agency may assume responsibility for administering the NPDES program, and this agency may make the water pollution control rules more rigorous than those designed by EPA.

The water pollution control rules investigated in the study were those which might be adopted by federal or state agencies. The feedlots to which the study was directed were those in Michigan and other similar areas in the north central and eastern states. The study was designed specifically to include those beef feedlots of less than 1000-head capacity.[3]

Several studies have been completed which analyzed the impact of environmental policies on the cost structures of feedlots (David, Seltzer and Eickhoff; Byrkett; Cross; Daiss; Johnson and Davis; Pherson). These analyses have been limited by the fact that production was viewed in a static context. It would be preferable to observe the paths of adjustment by feedlot operators in order to determine the effect of environmental policies on beef feedlot behavior. Upon the imposition of these policies, some operators may decrease production while others may continue to produce at historic levels. Some operators may change their input mix and become more capital intensive. Feedlots of different ages, capital positions, technology levels, and off-feedlot resource opportunities may have different paths of adjustment to the alternative rules. The intent of the methodology used in this study was to provide some insight into these adjustment paths.

[3] The vast majority of Michigan feedlots are included in this category since only 16 of the 1,696 Michigan feedlots were greater than 1000-head capacity in the 1969 census of agriculture (U.S. Department of Commerce).

Simulation Model

The model constructed for this study simulated the production behavior of individual firms over a multiperiod horizon. Its four components, illustrated in figure 1, are described below.

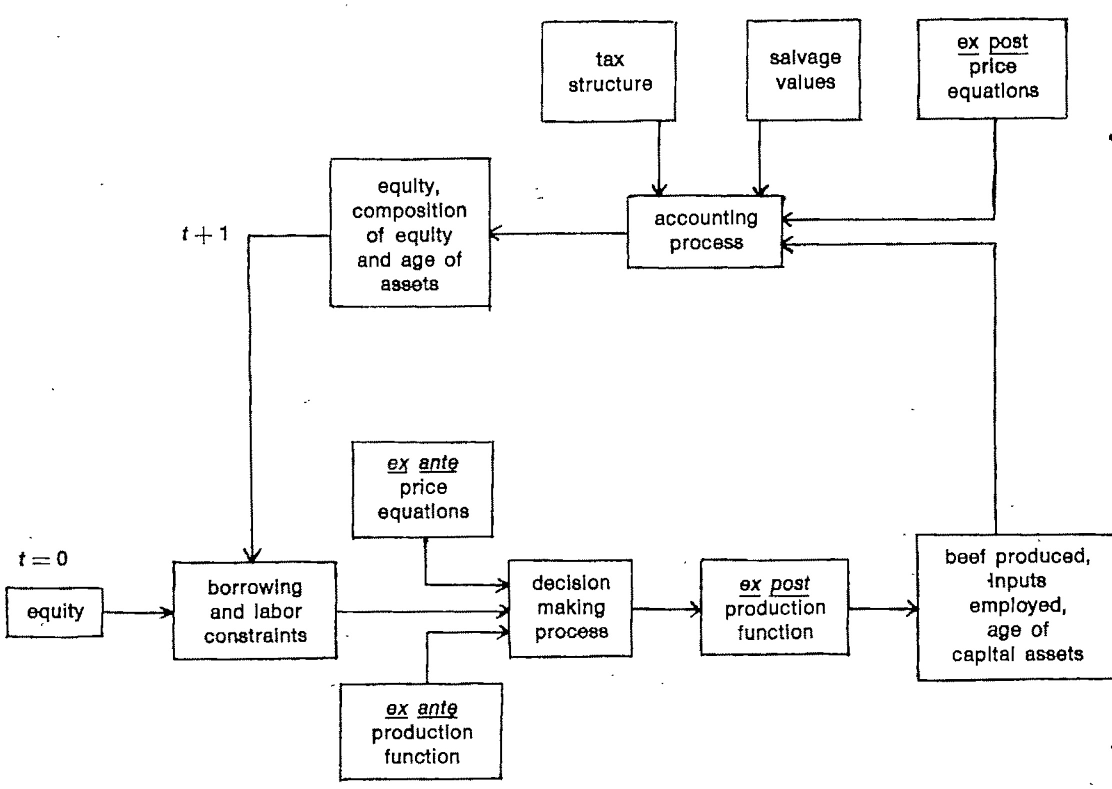

Figure 1. Model of feedlot behavior over multiple year horizon

A Farm Feedlot Component

The farm feedlot component assumed a whole farm approach to feedlot production by simulating feedlot design and beef production, the production of crops necessary to feed the cattle, the transportation of crops from field to storage facilities, the design of feed storage facilities, and the removal of wastes to the fields.[4] This component provided a production function for the remainder of the model and provided, with the help of the simulated decision-making process (component 3), some *ex ante* notion of the profitability of various farm-feedlot technologies at a given capacity. After the decision-making process determined the number of cattle to produce and the type of farm feedlot technology to employ, an *ex post* production function determined the costs and returns to the operation.

This component was capable of representing a broad range of feedlot sizes and technologies found in Michigan. Information concerning the number of cattle fed, the feedlot housing technology, the feed storage technology, and the water pollution control rules to which the firm was forced to comply was supplied. The model computed the physical quantities of buildings, machinery, land, labor, fuel, seed, fertilizer, feed supplement, etc., needed to produce the specified quantity of beef.[5] Given the beef output and the housing, feed storage, and pollution control technologies, the model assumed perfect complementarity of many inputs. Land, feed storage facilities, feedlot housing, feeding equipment, feeder calf purchases, and water pollution control inputs were all used in fixed proportions.

The quantity of feed used in the feedlot was a function of the feed ration, the number of beef fed, and the feeding efficiency as influenced by housing type. The necessary feed was produced with the minimum cost combination of inputs. Input levels were determined by (*a*) computing the amount of energy (measured in horsepower hours) required of various crop production activities, (*b*) computing the land and labor resources available for each activity, (*c*) selecting an array of machinery combinations which are typically used with each crop production activity, and (*d*) selecting the minimum cost equipment set which allowed the energy requirements to be met given the land and labor resources available.

Price Expectation and Price Realization Equations

Ex ante and *ex post* price equations were used to represent the feedlot operator's price expectations and output and input prices which were actually experienced by the operator (fig. 1). The actual prices experienced did not necessarily equal the price expectations for the period. For feeder and slaughter cattle, the *ex ante* prices were linear functions of last period's prices, and the *ex post* prices were based on equations which traced historic price cycles. Both the *ex ante* and *ex post* price equations were assumed independent of the firm's output.

The *ex ante* price equations for output and input prices were

$$(1)\quad SPLR^* = a_0 + a_1FDPR_t + a_2MARG_t + a_3DSLPR_t,$$

$$(2)\quad FDPR^* = SLPR^* - (SLPR_t - FDPR_t),$$

and

$$(3)\quad P^*_i = (1 + b_i)\,P_{t,i},$$

where $SLPR^*$ = the expected future price of slaughter cattle; $FDPR_t$ = actual price of feeder calves in month t; $MARG_t$ = slaughter and feeder calf price difference in t; $DSLPR_t$ = change in slaughter price over the past six months; $SLPR_t$ = slaughter price in month t; $FDPR^*$ = expected future price of feeders; P^*_i = expected future price index of input i (i = 1 for machinery, i = 2 for buildings, i = 3 for fertilizer, i = 4 for all other inputs); $P_{t,i}$ = actual price index of input i in month t; and b_i = expected annual inflation rate.

The *ex ante* slaughter price equation, equation (1), was estimated by ordinary least squares, substituting the monthly average

[4] Feedlot technology was one of five types—drylot unpaved, drylot paved, open lot, cold confinement solid floor, and cold confinement slotted floor. Feed storage technology included moist corn storage, tower silo storage, and bunker silo storage.

[5] This component was a by-product of an interdisciplinary research effort at Michigan State University. Personnel from Systems Science, Agricultural Economics, Crops and Soils, and Agricultural Engineering were involved in a research project with the objective of better understanding and managing the environment. Details of the construction can be found in Hughes. Data were from a variety of sources including engineering data from past research, small sample experiments, and estimates from reliable sources. Cost data were from surveys of input suppliers and secondary sources. Production data was from crop response and livestock feeding research.

slaughter price over the period t through $t + 12$ for the value of $SLPR^*$;[6]

$$SLPR^* = 7.0218 + \underset{(12.8672)}{0.7275\, FDPR_t} - \underset{(1.7591)}{0.1547\, MARG_t} + \underset{(0.5248)}{0.03602\, DSLPR_t},$$

$R^2 = 0.92,$

where the numbers in parentheses are t-statistics.

The coefficients b_1, b_2, b_3, and b_4 in equation (3) were set equal to an annual expected inflation rate of 5% over the simulated period. Thus, expected future price relationships of machinery, fertilizer, buildings, and other inputs were linear trends of current prices.

Ex post price equations were based on historic price movements. Franzmann and Walker used harmonic regressions to represent movements of feeder and slaughter cattle prices. These price equations provided *ex post* estimates of future feeder and slaughter prices which conformed with historic cyclic price movements in the beef marketing sector. The movement of *ex post* prices of farm machinery, buildings and fences, fertilizer, land, labor, and other inputs was similar to the *ex ante* prices for these inputs. The expected annual rates of price increases of machinery, buildings, fertilizer, and other inputs were equal to the mean movement in the price indices over the 1960–73 period (0.35, 0.02, 0, and 0.05) and a constant of 0.04 for each input thereafter (USDA 1960–73).

Decision-Making Model and Accounting Process

A decision-making process determined the type and level of inputs employed and was used each time period by each simulated firm (fig. 1). A modified version of the capital-rationing model was used to decide whether to produce beef with the old facilities, invest in new facilities, or invest in off-feedlot activities (Bernard). The model was

$$(4) \quad \max \sum_{n=1}^{10} (NPV_n)x_n + (NPV_c)x_c,$$

subject to

$$(5) \quad \sum_{n=1}^{10} I_{nt}x_n + I_{ct}x_c - B_t \leq net\ worth_t,$$

$$(6) \quad \sum_{n=1}^{10} L_n x_n + L_c x_c \leq labor_t,$$

$$(7) \quad (Blim)B_t \leq net\ worth_t,$$

and

$$(8) \quad \frac{head_c}{TR} \leq current\ capacity,$$

where x = level of feedlot production in 400-head units, n = the type of new feedlot technology available for acquisition, c = current feedlot technology type, B_t = amount of credit in year t from external credit sources, NPV = net present value, I_{nt} = investment of capital in feedlot type n in year t for a capacity level of 400 head, $net\ worth_t$ = operator's equity in year t, $labor_t$ = annual hours of labor available in year t, L = annual hours of labor required in a 400-head capacity feedlot unit, $Blim$ = inverse of maximum debt/equity ratio allowable, $head_c$ = current production from feedlot technology type c, and TR = turnover rate or animals produced annually/capacity.

Investments in each of n mutually exclusive new feedlot facilities had a net present value of

$$(9) \quad NPV_n = \sum_{t=0}^{T} \frac{R_t}{(1+r)^t} + \frac{SV_T}{(1+r)^T} - I_0.$$

The net present value of investments committed to an old facility was

$$(10) \quad NPV_c = \sum_{t=0}^{T-i} \frac{R_t}{(1+r)^t} + \frac{SV_T}{(1+r)^{T-i}} - SV_i,$$

where r is the off-feedlot rate of return, SV_T is the salvage value in the Tth year, R_t is the net cash flow in year t, I_0 is the original investment outlay, and i is the current age of the asset.

The investment in the current feedlot in equation (10) was assumed to be the salvage value of the durable assets and land or

$$(11) \quad SV_i = U^i I_i + P_{land,i},$$

where i is the age of the asset, U is a constant, I_i is the replacement value of the asset in year i, and $P_{land,i}$ is the market price of land in year i. Thus, the asset depreciated by $(U^{i-1}I_{i-1}) -$

[6] Monthly fed cattle prices of choice steers at Omaha, 900–1000 lbs., were employed to represent $SLPR_t$. $FDPR_t$ was represented by the monthly choice feeder steer cattle at Kansas City, 400–500 lbs.; $MARG_t$ was the difference between these two prices. $DSLPR_t$ was the monthly fed cattle minus the monthly fed cattle price which occurred six months prior.

(U^tI_t) during each time period, reflecting the user cost of the asset.

Returns and investment costs in new facilities were found by using the farm-feedlot production component. Setting capacity at 400 head, the farm-feedlot production component was used to identify operating and investment costs for each of the possible feedlot technologies.[7] Expected annual fund flows and investment costs were found for each time period by using the appropriate *ex ante* price expectation models.

The constraints on the annual investment decision specified that the total feedlot investment could not exceed the sum of borrowed and owned capital in any one year. $Labor_t$ was constrained to less than three full-time workers on the farm feedlot. The term *Blim* in equation (7) was established by the fourth component of the model which is described later. The constraint served to limit the amount of external credit in the feedlot.

Equation (8) enabled the decision-making component to consider capacity levels less than or equal to current capacity. If a new feedlot technology was more profitable at the present size level than the current technology, the constraint was removed during the next time period. The effect of this procedure was twofold. First, the investment alternatives were forced to be mutually exclusive. Second, any expansion program occurred over a two-year period.

An accounting process which computed and stored the financial position of the firm each year was appended to the decision-making model. The process used a market value concept in the firm's financial position by adding this year's land appreciation and net fund flow to last year's equity position while subtracting the user cost estimate of durable assets. The net fund flow included accrued income from the sale of slaughter cattle less accrued expenses for feeder cattle, fertilizer, herbicides, feed supplement, labor, fuel, insurance, property taxes, equipment and building repair costs, interest payment on taxes, and income taxes.

Optimization Procedure

The last component of the model, an optimization procedure, was employed to find the values of four unknown parameter values (initial net worth, the rate of return on off-feedlot investments, and the determinants of the amount of debt, and the annual user cost of durable assets). The values of these variables were those which enabled the model's output to perform consistently with historic data. Under the assumptions that the simulated feedlots were representative of Michigan feedlots and that the performance of each was independent of the group as a whole, changes in Michigan feedlots' production were examined through changes in the production of the twenty simulated feedlots. The simulation model's performance measure was a simple correlation coefficient between historic annual cattle and calves on feed, January 1 (U.S. Department of Agriculture 1959–73), and the annual simulated production.

The optimization procedure to find the four unknown parameter values involved two steps. The first step, the direct search method, assumed a strictly concave function for the value of the correlation coefficient in equation (12) (Beveridge and Schecter):

(12) correlation coefficient = f(net worth, debt constraint, opportunity cost of funds, determinant of user cost of durable assets).

The second step, a coarse grid approach, tested the assumption that the correlation coefficient in equation (12) was strictly concave. Several combinations of the unknown values of the four parameters were found by establishing a grid of "reasonable" values. These combinations were then used in the simulation model to find if any combination produced a higher correlation coefficient than the one found through the first step (Forster).

The optimization procedure was initiated by establishing reasonable values for the determinant of the shape of the net worth distribution of simulated feedlots (K), the determinant of the user cost of durable assets (U), the opportunity cost for funds (r), and the debt constraint (*Blim*). Initial equity positions were established for twenty simulated firms by randomly selecting from the net worth distribution whose shape was determined by K. Each firm's behavior was simulated over the 1960–70 period using the initial values of K, U, r, and *Blim*. The annual feedlot capacity of the twenty simulated firms was then compared to annual Michigan cattle and calves on feed data. The two-step optimization procedure

[7] A unit of 400 head was used since the farm feedlot production component demonstrated nearly constant returns to scale at capacities greater than 400 head (Hughes, appendix).

was employed to find new values for the parameters, and the twenty-firm simulation over the 1960–70 period was repeated.

The determinant of the shape of the net worth distribution was a parameter in the Erlang function:

$$(13)\qquad f(b) = \frac{(aK)^K\,(bK)^{K-1}\,(e^{-abK})}{(K-1)!},$$

where $f(b)$ = probability of b net worth, a = 1/mean net worth where mean net worth is an assumed value, and K = parameter to be determined. By varying the parameter K, the density function assumes a variety of distributions from the exponential distribution to the normal distribution.

The parameter values identified by the first step of the optimization procedure, the direct search method, were $K = 2$, $Blim = 1.5$, $r = 0.0697$, and $U = 0.9022$. The coarse grid approach was then used. A priori knowledge of the structure of midwestern farms indicated that the net worth distribution is skewed to the right. Therefore, in using the coarse grid method, K was limited to values 1, 2, and 3. The inverse of the maximum debt/equity ratio ($Blim$) was limited to 1.00, 1.25, and 1.50. The opportunity cost of funds (r) was restricted to 0.04, 0.06, and 0.08. The determinant of the user cost (U) was limited to 0.8 and 0.9. Several points on the grid developed using these combinations of values produced correlation coefficients which had greater values than the correlation coefficient of 0.885, which was associated with optimum values for the variables found through the direct search method. The point on the grid with the largest correlation coefficient (0.967) was associated with $K = 2$, $Blim = 1.25$, $r = 0.06$, and $U = 0.90$.

A sensitivity analysis indicated that parameters critical to the model's performance included the determinant of the firm's debt, the determinant of the user cost of durable assets, the initial net worth of the simulated firms, and the initial age of the feedlots. Small changes in these parameter values strongly influenced the operator's ability to enlarge feedlot capacity. In addition, the initial age of feedlot facilities affected a feedlot's performance. Recently built, capital-intensive feedlots with large differences between the discounted value of future cash flows and the salvage value of assets tended to be locked into production patterns compared to older, depreciated facilities. Parameters which were found to have little impact on the firm included rate of earnings on off-feedlot investments and changes in the initial net worth distribution of feedlot operators.

Simulated Feedlot Performance, 1960–73

Table 1 shows the simulated firms' annual performance measures over the 1960–73 period. The mean net worth of the simulated firms in 1960 was $78,541. Net worth expanded during the 1960–73 period to $199,793, and feedlot capacity expanded from a mean 207.2 head in 1960 to a mean of 287.5 head in 1973. The production cost/asset ratios increased over this time period reflecting changes in input price ratios over the period. Generally, vari-

Table 1. Measures of Performance for the Simulated Feedlots

Year	Mean Feedlot Capacity	Production Costs/ Assets	Weighted Average Return	Mean Owner Equity
	(Head)	(Ratio)	(Ratio)	($)
1960	207.2	0.0713	0.0847	78,541
1961	207.2	0.0748	0.0766	82,900
1962	206.3	0.0779	0.0702	87,354
1963	214.3	0.0803	0.0680	92,800
1964	215.0	0.0838	0.0550	97,412
1965	224.7	0.0863	0.0643	104,243
1966	225.4	0.0900	0.0656	111,742
1967	232.7	0.0936	0.0564	119,139
1968	239.1	0.0968	0.0533	127,434
1969	246.7	0.1008	0.0597	137,791
1970	256.6	0.1048	0.0570	149,339
1971	266.7	0.1091	0.0609	163,269
1972	278.2	0.1130	0.0692	180,456
1973	287.5	0.1176	0.0690	199,793

Table 2. Actual Measures of Performance

Year	No. of Head Bought	Production Costs/Assets	Return to Operator's Investment	Operator's Investment
1967	189	0.106	0	140,066
1969	222	0.106	0.063	168,745
1970	206	0.093	0.050	181,561
1972	262	0.116	0.070	228,146

able costs increased at a faster rate than prices of durable assets over the period, causing the ratio to gradually increase.

The net worth and capacity data by year correspond well with a priori expectation and with historic feedlot data in selected years (Kyle). To see this one need only compare actual measures of performance contained in Michigan State University's Telfarm Reports (table 2) with similar measures of performance in table 1. The model was tentatively accepted as meeting the test of consistency with real world performance.

Feedlot Performance, 1974–85, under Alternative Pollution Control Rules

Five different rules outlined in table 3, which might be employed by state or federal agencies in controlling beef feedlot pollutants were examined. Rules A through D were implemented in a manner that would provide an upper limit to the estimate of the effect of the rules. The runoff control technology employed was an abatement system which included a diversion terrace, settling basin, holding pond, fencing around the holding pond, and a pump and irrigation system to empty the pond. The operating costs and capital outlay of a system were functions of the type of housing used in the feedlot, the capacity of the feedlot, the amount of exposed feedlot surface, and the solid waste runoff storage capacity requirements. To date, rules issued by the EPA have been in the form of directives specifying the level of effluent limitation to be attained, and the feedlot operator is allowed some discretion in combining inputs in order to achieve the effluent limitation. The runoff abatement system used in the simulation model would likely be the most severe control technology that an operator would apply.

Table 3. Alternative Water Pollution Control Rules Analyzed

Rule	Provision
A	Current EPA guidelines would be expanded to all feedlots. Facilities must be constructed to control the runoff from a 10-year, 24-hour rainfall event by 1977 and the runoff from a 25-year, 24-hour rainfall event by 1983. (For Michigan, 10-year, 24-hour and 25-year, 24-hour rainfall events are equal to approximately 5 inches and 6 inches, respectively.)
B	All feedlots must construct facilities by 1977 to control runoff from a 25-year, 24-hour rainfall event.
C	All feedlots must construct facilities by 1977 to control all runoff from the rainfall occurring in any 6-month interval. (For Michigan, this rainfall would be equal to approximately 16 inches.)
D	All feedlots must construct facilities by 1977 to control all runoff from the rainfall occurring in any 6-month interval. Also, the feedlot may not spread solid waste during winter months.
E	Feedlots are neither required to control runoff nor prevented from spreading solid waste.

The behavior of Michigan feedlots over the 1974–85 period was simulated under each of the five rule alternatives. Four measures of performance—feedlot capacity, ratio of annual production costs to market value of assets, weighted average return to equity, and annual equity position—were selected to characterize feedlot behavior. The use of the ratio of production costs to value of assets is an attempt to measure asset fixity. Pollution control rules which reduce this ratio lead to more desirable inputs and increases asset fixity. The mean value of the annual equity of the simulated firms is compared to the annual equity for firms with no pollution control imposed. The "equity loss" of a particular rule was found by comparing the present value of annual equity changes with the changes when no control was imposed.

Feedlot behavior under rule E, the "no action" rule, was the norm with which performance under the other rules was compared. The annual performance variables of the simu-

Table 4. Measures of Performance for the Simulated Feedlots without Imposing a Water Pollution Control Rule

Year	Mean Feedlot Capacity	Production Cost/ Asset	Weighted Average Return	Mean Owner Equity
	(Head)	(Ratio)	(Ratio)	($)
1974	283.6	0.1261	0.0669	219,857
1975	319.3	0.1264	0.0724	245,872
1976	330.4	0.1307	0.0753	276,005
1977	344.2	0.1331	0.0730	309,758
1978	351.8	0.1365	0.0764	348,573
1979	361.9	0.1373	0.0730	391,192
1980	361.2	0.1379	0.0747	439,248
1981	367.4	0.1371	0.0728	492,300
1982	366.1	0.1364	0.0726	550,797
1983	367.3	0.1346	0.0713	615,091
1984	366.5	0.1355	0.0690	683,933
1985	367.6	0.1366	0.0679	758,685

lated feedlots are shown in table 4. Production expands approximately 29% during the 1974–85 horizon. Most of this increase occurs in the 1974–79 period, reflecting the effects of the cyclical *ex post* price relationships. The asset structure remains rather stable over the 1974–85 period due to the constant input price ratios assumed for the period. The average equity position of the simulated firms expands from $220,000 in 1974 to $750,000 in 1985, reflecting an 11.5% annual increase in the equity of the simulated firms.

Upon the imposition of each of the four rules, feedlot behavior is affected. Under rule A, the control of runoff from a ten-year, twenty-four hour rainfall event by 1977 and a twenty-five year, twenty-four hour rainfall event by 1983, production declines and equity losses are incurred relative to rule E, the "no action" rule. The mean decline in production is 7.0 head per firm over the entire twelve-year period under rule A relative to production under rule E. This relative decline represents 0.167% of production over the twelve-year period under rule E. The present value of annual differences in equity changes over this period as a result of rule A is $3,724 per firm. This equity loss represents 1.69% of the mean 1974 equity of the simulated firms. Results from imposing rule A and the other three rules are shown in table 5.

After the imposition of any of the four selected water pollution control rules, asset structure and profitability of the feedlot changed very little. The ratio of variable assets to total assets changed little among rule alternatives, and the rate of return on equity is nearly the same in any year across simulations under alternative rules.

To measure the degree of regressiveness of the alternative water pollution control rules, feedlot production was simulated with the mean 1974 feedlot equity at two levels. The first level was with a mean net worth of nearly $220,000 (the same equity level used to make the estimates in table 5). The second level was with a mean net worth of approximately $105,000. For simulated feedlots with the lower 1974 net worth, the four alternative water pollution control rules presented equity losses relative to the "no action" rule of 3.13¢, 3.31¢, 4.74¢, and 5.46¢ per dollar of 1974 equity. These relative losses are nearly double those calculated for the feedlots with larger equity positions (table 5).

Conclusions

The beef feedlots of less than 1000-head capacity would change their performance only slightly under any of the alternative water pol-

Table 5. Impact of Alternative Water Pollution Control Rules on the Production and Equity Positions of Michigan Beef Feedlots, 1974–85

	A	B	C	D
Present value of equity loss ($)	3,724	3,911	4,800	5,990
Relative production decline (%)	0.1670	0.1700	0.9000	0.9100
Equity loss per dollar 1974 equity ($)	0.0169	0.0178	0.0218	0.0272

lution control rules tested. Under rule A, the rule extending current EPA effluent guidelines to less than 1000-head lots, production is decreased by 0.167% relative to production under the "no action" rule. The most severe rule, imposing the control of a six-month rainfall plus prohibiting winter spreading of wastes, reduces production by only 0.91% relative to production under the "no action" rule.

The alternative rules tested would impair the net worth positions of feedlot owners over the 1974–85 period compared to their net worth positions if no rules are imposed. When EPA guidelines are extended to feedlots of less than 1000-head capacity (rule A), the present value of the relative "loss" in net worth is $3,724 per firm. With the most severe rule, rule D, present value of the relative loss in net worth is $5,990. Moreover, this loss was 2.72¢ per dollar of 1974 net worth.

The rules do raise equity questions which must be considered by decision makers along with the benefits and costs associated with a particular rule. Assuming the mean net worth of simulated firms is reduced to $105,000 or approximately half the net worth assumed for the cost estimates, relative equity loss per dollar on 1974 equity nearly doubles under all four rules. The economies of size associated with water pollution control technology results in a regressive impact under any of the alternative rules.

Other results from the analysis indicate that costs which the feedlots bear as a result of the rules investigated vary with feedlot technology. For the feedlot with open lot construction, costs are larger than the costs borne by more confined facilities. These high abatement costs may even result in a shift to more land-intensive feedlot construction. The effects of the alternative rules appear to be nearly the same regardless of feedlot age. Feedlot operators' asset structure is affected only slightly by these rules, and asset fixity is not noticeably increased.

The model used in this study has several advantages over the traditional static analysis used in economic impact studies. These advantages are derived from the flexibility of the model and the dynamic attributes of the model. The flexibility of the simulation model allows a variety of assumptions to be made concerning the resource levels or technical characteristics of a group of simulated firms in order to observe the adjustment process of classes of firms. For example, it allows a rather precise identification of the regressive nature of proposed rules and an identification of those types of firms which suffer the greatest financial hardship in the adjustment process. The dynamic nature of the model allows a representation to be made of the reaction of individual firms to the rules over time. It allows firms to reduce or discontinue the production of beef or to produce at historic levels. It allows adjustments to be made in the resources employed in the production process and allows for the observation of adjustments. While the model has disadvantages in terms of the cost requirements of the analysis, the model offers several advantages in terms of its flexibility and dynamic attributes.

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The Role of Sectoral Technical Change in Development: Japan, 1880–1965

Mitoshi Yamaguchi and Hans P. Binswanger

The goal of this study is to understand and measure the effect of differential rates of technical change in the agricultural and nonagricultural sector on per capita income growth and sectoral allocation of income and factors of production. A fairly simple dynamic general equilibrium model with an agricultural and nonagricultural sector was constructed along neoclassical lines (but including labor market imperfections) and applied to Japanese data from 1880 to 1965. Nonagricultural technical change contributed more to per capita income growth than agricultural technical change. The latter also tends to push resources, particularly labor, out of the agricultural sector.

Key words: technical change, employment, agriculture, development, Japan.

The recent experience of the Green Revolution has focused the attention of economists on the role of agricultural technical change as a powerful engine of growth. Increased allocation of resources to agricultural research at national and international levels highlights this changing emphasis. At the same time, this emphasis also causes worries about possible adverse employment effects of technical change. Technical change in agriculture generally reduces the amount of capital and labor needed to produce a given level of output. Offsetting increases in labor use requires either increases in rates of growth of agricultural output, a lowering of agricultural wage rates—which is highly unattractive—or a transfer of labor to nonagricultural activities. Since technical change in agriculture increases per capita income in the economy and tends to reduce agricultural prices, we can expect a positive effect on agricultural and nonagricultural demand to occur as a result of the technical change. But how big these effects will be is largely a guess. It is also likely that the increased demand alone generated by the technical change will be insufficient to prevent downward pressure on the real wage rate. If this should be the case, what then are the most attractive policy alternatives to generate demand for the labor released by the agricultural technical change?

In an attempt to answer these questions and to get some feel for the magnitudes of income-generating and labor displacement effects, a relatively simple dynamic general equilibrium model with an agricultural and a nonagricultural sector was constructed along neoclassical lines. The economy is closed, but it is not too difficult to evaluate how the opening of the economy would affect the conclusions. The model relates technical change in the two sectors—capital accumulation and labor and population growth—to per capita income, sectoral outputs, allocation of resources, and terms of trade. Instead of simulating with the model, we use it to measure the impact of the exogenous variables on the endogenous ones at different states of the development of Japan, i.e., we trace structural changes in that economy. In addition, the model is used to measure the contributions of the exogenous variables to per capita income for each decade from 1880 to 1960. The focus of the study, therefore, is on growth accounting in a general equilibrium context.

In this model, technical change is treated as sector specific, i.e., productivity advances in

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the agricultural production process have no impact on the efficiency of the nonagricultural production process. This strongly differentiates the model from apparently similar work of Kelley and Williamson.[1]

Technical change is also viewed as the result of an investment activity in basic and applied research. It is therefore quite similar to physical capital accumulation. These two investment categories compete for the aggregate savings of the economy (as does investment in human capital, which is not considered in the model). To prevent asymmetric treatment of the investment activities, saving and investment are not treated endogenously in the model. Rather, capital accumulation rates and rates of technical change are treated exogenously. This is appropriate because these variables can be viewed as policy targets and because the goal of this study is to find out what the effect of changes in these rates are on per capita income and other endogenous variables.[2]

The disadvantage of not modeling both investment categories endogenously is that no way exists in the model to tell whether the economy allocated its overall investment resources efficiently to physical capital accumulation and to generating technical changes in the two sectors. For example, one finding of this study is that a 1% increase in nonagricultural technical change has a higher effect on per capita income growth than a similar increase in the rate of agricultural technical change. Does this mean that the economy should allocate more resources to nonagricultural technical change? This question cannot be answered without data on how much it costs to achieve a 1% increase in each of these rates of change. If nonagricultural technical change is more expensive than agricultural technical change, it may still be better to concentrate on the latter. The model, therefore, can only assess benefits of alternative courses of action. This is a deficiency which it shares with other growth-accounting frameworks.

The Model

The model is discussed in detail elsewhere (Yamaguchi 1973; Yamaguchi and Binswanger).[3] It is basically a two-sector model along neoclassical lines. The economy is closed. The following variables (or their rates of change) are assumed to be given exogenously: population, labor force (or participation rate), capital stock, rate of technical change in agriculture, and rate of technical change in nonagriculture. The endogenous variables of the system are: per capita income, agricultural output, nonagricultural output, sectoral allocation of labor, sectoral allocation of capital, and terms of trade. As a departure from usual growth models, population and labor force are treated independently to permit an evaluation of the role of changes in the labor participation rate on per capita income.

Production functions in both sectors are Cobb-Douglas with neutral technical change.[4]

[1] The transferability issue is rather complex. Clearly many basic scientific advances ultimately lead to increase in factor productivity in almost all sectors of an economy. A new metal alloy or a synthetic material is an example of a basic advance which can be used in many sectors. But advances in genetics will never lead to factor productivity increases in textiles. Moreover, as is shown in Binswanger (in press), basic scientific advances lead to actual increases in factor productivity only if they are translated into specific production techniques or new inputs by an applied research effort. And the results of these applied efforts are almost always highly sector specific. Plant breeding has no effect on industrial productivity whatsoever. New pesticides, even though developed in the industrial sector, only affect agricultural factor productivity. Basic mechanical advances will pay off in terms of agricultural productivity only if the machinery industry spends the development and engineering resources to incorporate them into agricultural machines, but these expenditures will have no payoff in terms of industrial productivity. Therefore, it seems more realistic to assume nontransferability of technical change in a growth model context. This view is supported by empirical evidence on rates of technical change in agriculture and nonagriculture, which differed strongly in the U.S. over the past century and also differed in Japan (see table 4).

Kelley, Williamson, and Cheetham; Kelley and Williamson assumed technical change to be a factor augmenting with identical augmentation rates in both sectors. Therefore, rates of technical change cannot vary independently in the two sectors, which assumes either transferability of technical change or coincidental equality of rates.

[2] A fuller model would treat physical capital accumulation and research investment in a symmetric fashion where the total savings of the economy are allocated to the two investment activities according to expected rates of return. Such a model would be much more complicated and empirical knowledge on the necessary research functions in such a model is not available.

[3] A model similar to this one has been presented in Tolley and Smidt, who used it to assess the effect of technical change in agriculture on per capita income growth in the U.S. from 1930 to 1960. Our model departs from theirs in that it introduces population explicitly in the model and treats the labor participation rate as a variable. They also do not consider the role of nonagricultural technical change.

[4] Table 2 shows that the nonagricultural labor share stayed stable (with some disturbances in the 1960s), while table 4 shows that the capital accumulation rate of the economy exceeded the labor growth rate. Therefore, either the elasticity of substitution was close to one with neutral technical change or technical change must have been labor saving. In the absence of any strong evidence for either of these hypotheses, the simpler neutrality hypothesis was chosen.

For agriculture there exists empirical evidence for Japan (Binswanger 1975) that technical change was not labor saving relative to capital, but that it was labor saving relative to land. The assumption of overall neutrality, therefore, does not do too much

Table 1. The Static Model

Equation	
$Y_1 = aQP^{\eta} E^{\epsilon}$	Agricultural demand function
$Y_1 = T_1 L_1^{\alpha} K_1^{\beta} B^{(1-\alpha-\beta)}$	Agricultural production function
$Y_2 = T_2 L_2^{\gamma} K_2^{\delta}$	Nonagricultural production function
$L_1 + L_2 = L$; $K_1 + K_2 = K$	Adding up constraint
(1.1) $w_1 = \alpha P_1 (Y_1/L_1)$; (1.2) $w_2 = \gamma P_2 (Y_2/L_2)$; (1.3) $r_1 = \beta P_1 (Y_1/K_1)$; (1.4) $r_2 = \delta P_2 (Y_2/K_2)$	Value of marginal product equals factor price
(1.5) $w_1 = m_w w_2$; (1.6) $r_1 = r_2$	Factor mobility condition
$P_1 Y_1 + P_2 Y_2 = P'QE$	Income identity

Note:
$i = 1,2$ = agricultural and nonagricultural sector, respectively.
P_i = sectoral output prices.
$P = P_1/P_2$ = terms of trade.
P' = general price level.
$w_i; r_i$ = sectoral wage and capital rental rates.
T_i = sectoral level of technical efficiency.
Q = population.
E = real per capita income.
m_w = agricultural wage rate as a proportion of nonagricultural wage rate.
a = agricultural demand shifter.
η, ϵ = agricultural price and income elasticity.
α, β = output elasticity of agricultural labor and capital.
γ, δ = output elasticity of nonagricultural labor and capital.
λ = proportion of income generated in agriculture.

Table 1 summarizes the model and the notation. The agricultural demand function includes an autonomous demand shifter which picks up changes in tastes and consumption not reflected in the demand elasticities.

A special feature of the model is the introduction of a market imperfection in the model in the form of an exogenous differential of the wage rate between the two sectors. As can be seen from table 2, the proportion of labor in agriculture (L_1/L) far exceeds the proportion of agriculture in output (λ). This large difference cannot be explained by the factor intensity differences in the two sectors (table 2). On the basis of the labor coefficients α and γ of the production functions, agriculture should be less labor intensive than nonagriculture. The high value of L_1/L has to be explained by lower factor rewards in agriculture. The introduction of the market imperfection into the model is necessary to make it consistent with these observed facts. The market imperfection implies that labor is more productive in the nonagricultural sector, which will be reflected in the conclusions. The imperfection also affects the form of the transformation curve between the two sectors. Johnson showed that if one combines two Cobb-Douglas production functions into a transformation curve, the result is a transformation curve with very little curvature, unless one chooses output elasticities which differ radically between the sectors. Furthermore, if one adds a market imperfection between the two sectors, the distorted transformation curve so defined can easily lose the curvature which it has and may become convex rather than concave to the origin.[5]

The static version of the model can be transformed into an eight-equation model of the form, $Ax = b$, where A is the matrix of structural parameters, x a vector of rates of change

violence to reality. Also, using labor-saving rather than neutral technical change in agriculture would strengthen rather than weaken the main conclusion of this paper.

The empirically observed labor-saving character (relative to land) of technical change in Japan does not invalidate Hayami and Ruttan's thesis of the role of induced innovation in agricultural development, because the path on which Japan experienced labor-saving technical change is extremely labor using relative to the path on which the U.S. experienced labor-saving technical change. For a detailed discussion see Binswanger (1975).

[5] Strictly speaking, the imperfection pushes the production point inside the economy's undistorted transformation curve. But one can redefine a new distorted transformation curve for any level of the market imperfection which lies everywhere inside the undistorted transformation curve. The flatness of the distorted transformation curve implies that changes in demand have little influence on the sectoral terms of trade.

Table 2. Parameter Values for Matrix A of Structural Parameters

Year	Labor's Share in Agr. Output[a] $\alpha = \frac{w_1L_1}{Y_1}$	Capital's Share in Agr. Output[a] $\beta = \frac{r_1K_1}{Y_1}$	Labor's Share in Nonagr. Output[b] $\gamma = \frac{w_2L_2}{Y_2}$	Capital's Share in Nonagr. Output[b] $\delta = \frac{r_2K_2}{Y_2}$	Price Elast. of Agr. Demand[c] η	Income Elast. of Agr. Demand[c] ϵ	Prop. of Labor in Agr.[d] $\frac{L_1}{L}$	Prop. of Capital in Agr.[e] $\frac{K_1}{K}$	Share of Income Produced by Agr.[f] $= \frac{P_1Y_1}{P'QE}$
1880	0.58	0.12	0.70	0.30	−0.60	0.40	0.75	0.63	0.47
1885	0.57	0.12	0.70	0.30	−0.60	0.40	0.68	0.59	0.30
1890	0.54	0.12	0.70	0.30	−0.60	0.40	0.63	0.55	0.32
1895	0.54	0.11	0.70	0.30	−0.60	0.40	0.60	0.50	0.31
1900	0.56	0.10	0.70	0.30	−0.60	0.40	0.57	0.44	0.32
1905	0.55	0.11	0.70	0.30	−0.60	0.40	0.55	0.40	0.34
1910	0.56	0.11	0.70	0.30	−0.60	0.40	0.54	0.35	0.34
1915	0.55	0.12	0.65	0.35	−0.60	0.40	0.53	0.29	0.28
1920	0.55	0.12	0.70	0.30	−0.60	0.45	0.51	0.22	0.26
1925	0.59	0.11	0.70	0.30	−0.60	0.45	0.49	0.19	0.24
1930	0.61	0.12	0.70	0.30	−0.60	0.35	0.47	0.16	0.19
1935	0.55	0.13	0.65	0.35	−0.60	0.35	0.44	0.14	0.21
1940	0.55	0.10	0.65	0.35	−0.60	0.35	0.42	0.11	0.16
1945	0.55	0.10	0.70	0.30	−0.60	0.45	0.44	0.10	0.27
1950	0.55	0.10	0.85	0.15	−0.60	0.45	0.45	0.09	0.22
1955	0.65	0.12	0.85	0.15	−0.60	0.45	0.38	0.09	0.18
1960	0.57	0.13	0.75	0.25	−0.60	0.45	0.30	0.08	0.13
1965	0.60	0.16	0.70	0.30	−0.60	0.45	0.24	0.07	0.08

[a] Recalculated from the data in the appendix of Yamada and Hayami to fit the factor definitions used here.
[b] Developed from Sato. The share after 1930 is calculated by taking the five-year average, centering the years shown on p. 279 of Sato. No data could be obtained before 1930. Therefore, we assumed that labor's share in nonagriculture was 70% and capital's share was 30%.
[c] Adopted from Kaneda and Yuize.
[d] Total agricultural labor is from Okawa, Shinohara, and Umemura (p. 218, table 33) and total labor data from Bank of Japan (p. 56).
[e] Agricultural and total capital were obtained from Okawa, Shinohara, and Umemura (p. 154, table 3) and Bank of Japan (p. 212, table 29) and a net total capital from Bank of Japan (p. 149, table 1). The proportion of total capital in agriculture can be obtained from these two series until 1940. Total capital data after 1940 can only be obtained from Okawa, Shinohara, and Umemura. This is the value in 1960 prices which was converted into average 1934–36 prices. This total capital is measured in gross terms instead of net terms, but it is assumed that the growth rates of gross and net capital stock do not differ. Then the series is spliced with the net total capital series before 1940. For agricultural capital the data after 1940 are available.
[f] Total national income comes from Bank of Japan and the value of agricultural output from Okawa, Shinohara, and Umemura.

of the eight endogenous variables, and b a vector of rates of change of the exogenous variables.[6] This system is summarized in table 3, where dots on the variables denote growth rates.

The inverse of A displays growth rate multipliers (GRM). For example, the 2, 4 element of A^{-1} is the partial derivative $\partial\dot{Y}_2/\partial\dot{L}$, which indicates by how much an increase in the growth rate of labor will increase the growth rate of nonagricultural output.[7]

Estimates of the parameters of the matrix A and the inverse GRM were obtained for five-year intervals from 1880 to 1965. Changes in the GRM trace structural changes in the economy.[8]

By multiplying the GRM of each decade by the corresponding decade rates of change of the exogenous variables as they occurred in Japan, one can measure the contribution of the exogenous variables to the observed rate of changes of the endogenous variables, i.e.,

$$(\partial\dot{E}/\partial\dot{L}_2)_t\,\dot{L}_t = (A^{-1})_{8,4}\,\dot{L}_t = ELC,$$

where ELC (E for income, L for labor, C for contribution) is the measured contribution of the growth rate of labor to per capita income growth at time t.

[6] The derivation of equations (3.1) to (3.8) is straightforward except for (3.6) and (3.7), which are complicated due to the market imperfection and because they combine equations (1.1) to (1.6) into two equations. For details see Yamaguchi (1973).

[7] For some of the exogenous variables the GRM are sums of two elements of A^{-1} since the variable enters on the right-hand side of two equations.

[8] The parameters of the model are obviously not assumed to be constant over the period. Therefore, structural changes in the economy can be traced by measuring how the effect of the exogenous variables has changed over time. In a small model like this one, it would be hazardous to assume that the structural parameters of the model remain unchanged over the entire period of eighty-five years even if one were to use it for simulation.

One reason for nonconstancy of the parameters of the model is the fact that simple functional forms, which are analytically convenient, were chosen. Recognizing that the simple forms may be only approximations to the true but more complex forms forces one to admit that the parameters of the simple forms may change over time.

Table 3. The Model in Dynamic Form

Equation No.	Coefficients of the A Matrix of Structural Parameters								Vector x of Endogenous Variables	Vector b of Exogenous Variables
(3.1)	1	0	0	0	0	0	$-\eta$	$-\epsilon$	$\dot{Y}_1$	$\dot{a} + \dot{Q}$
(3.2)	1	0	$-\beta$	0	$-\alpha$	0	0	0	$\dot{Y}_2$	$\dot{T}_1 + (1 - \alpha - \beta)\dot{B}$
(3.3)	0	1	0	$-\delta$	0	$-\gamma$	0	0	$\dot{K}_1$	$\dot{T}_2$
(3.4)	0	0	0	0	$\frac{L_1}{L}$	$\frac{L_2}{L}$	0	0	$\dot{K}_2$	$\dot{L}$
(3.5)	0	0	$\frac{K_1}{K}$	$\frac{K_2}{K}$	0	0	0	0	$\dot{L}_1$	$= \dot{K}$
(3.6)	0	0	1	-1	-1	1	0	0	$\dot{L}_2$	$\dot{m}_w$
(3.7)	0	0	$\gamma - \alpha$	0	$\alpha - \gamma$	0		0	$\dot{P}$	$\dot{T}_2 - \dot{T}_1 - (1 - \alpha - \beta)\dot{B} + a\dot{m}_w$
(3.8)	γ	$1 - \lambda$	0	0	0	0	0	-1	$\dot{E}$	$\dot{Q}$

Data and Results

The structural parameters used for the A matrix are tabulated in table 2. Throughout the period the nonagricultural sector is more labor intensive than the agricultural sector ($\gamma > \alpha$). The price and income elasticities for food demand are the ones reported by Kaneda. He found that they are fairly high and changed little over time. Also, agriculture's share of total income was 47% in 1880 and declined steadily to 8% in 1965.

The rates of change of the exogenous variables are summarized in table 4. The rates of technical change were measured using equations (3.2) and (3.3) of table 3. This is the familiar Solow approach. The average rate of nonagricultural technical change exceeded the agricultural rate of technical change, but the former fluctuated much more than the latter. Population growth rates were low and larger after the turn of the century than before. The labor force grew at about the same average rate as did population, but these rates differed strongly in the short run.

Table 5 summarizes the rates of change of the endogenous variables. The decline of agriculture's share in income is shown clearly in the absolute decline of the agricultural labor force and the much slower rise of agricultural capital than of nonagricultural capital. Terms of trade turned in favor of agriculture throughout most of the period.

A comparison of the GRM of technical change with those of capital and labor is shown in figure 1. The sum-of-the-two technical change multipliers does not exceed the sum of the capital plus labor multipliers by very much. (The labor multiplier shows the effect of a rise in labor without a corresponding rise in population, i.e., the effect of a rise in the labor participation rate.) The approxi-

Table 4. Average Annual Growth Rates of Exogenous Variables in Percent per Year

Decade	Agr. T.C.[a] $\dot{T}_1$	Nonagr. T.C.[a] $\dot{T}_2$	Capital[b] $\dot{K}$	Labor[c] $\dot{L}$	Population[c] $\dot{Q}$
1880	3.73	8.04	2.15	1.46	0.86
1890	2.18	1.00	1.71	0.93	0.95
1900	2.44	−0.80	2.13	0.55	1.16
1910	5.03	3.50	3.56	0.41	1.21
1920	1.41	5.30	2.93	0.83	1.42
1930	3.81	1.55	3.27	0.93	1.13
1940					1.56
1950	4.10	10.30	5.78	2.25	1.17
1960				1.33	1.04
Average for total period	3.24	4.12	3.08	1.09	1.17

Note: For computational details, see Yamaguchi (1973).
[a] From Yamaguchi (1973).
[b] From Okawa, Shinohara, and Umemura (vol. 3).
[c] From Bank of Japan.

Table 5. Average Annual Growth Rates of Endogenous Variables in Percent per Year

Decade	Per Capita Income[a] E	Agr. Output[b] Y_1	Nonagr. Output[c] Y_2	Agr. Labor[b] L_1	Nonagr. Labor[c] L_2	Agr. Capital[b] K_1	Nonagr. Capital[d] K_2	Terms of Trade[c] P
1880	6.25	3.70 (2.93)[e]	13.01	−0.26 (−0.26)[e]	5.45	0.13 (0.65)[e]	1.50	2.33
1890	2.53	2.46 (1.42)	3.48	−0.06 (−0.05)	2.43	0.46 (1.00)	2.50	0.50
1900	0.13	4.77 (2.42)	1.01	−0.11 (−0.27)	1.42	0.84 (1.72)	2.80	−0.41
1910	3.51	5.21 (2.95)	5.52	−0.10 (−1.22)	0.94	0.50 (0.93)	4.70	0.83
1920	0.76	1.46 (1.50)	7.50	0 (0.02)	1.64	0.71 (1.05)	2.80	0.41
1930	2.41	3.76 (1.06)	4.09	−0.29 (−0.29)	1.94	0.35 (0.72)	4.00	3.73
1940		(−0.20)		1.74 (1.74)		(−1.40)		
1950	9.52	4.93 (5.36)	15.48	−1.74 (−1.74)	4.71	(4.56)		
1960		(5.46)		−3.34 (−3.34)	3.14	(6.74)		
Average	3.59	3.76	7.16	−0.46	2.71	0.50	3.05	1.23

Note: For computational details, see Yamaguchi 1973.
[a] From Bank of Japan for 1880–1964; from Bureau of Statistics for 1964 on.
[b] From Okawa, Shinohara, and Umemura, vol. 9.
[c] From Bank of Japan; Okawa, Shinohara, and Umemura, vol. 9.
[d] From Okawa, Shinohara, and Umemura, vols. 3, 9.
[e] The values in parentheses are new values from Yamada and Hayami.

mate equality of these sums suggests that technical change is not inherently a more powerful engine of growth than the traditional endowments. Overall, however, technical change has contributed more to the observed growth rates of per capita income than have the growth of capital and labor (table 6). This is due to the fact that the rates of technical change exceeded the growth rates of capital and labor (see table 4).

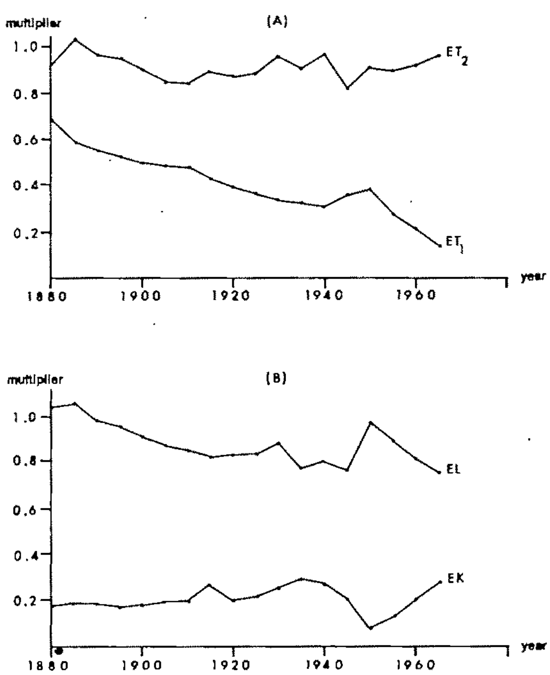

Figure 1. GRM with respect to per capita income. ET_1 = GRM of agricultural technical change on per capita income. ET_2 = GRM of nonagricultural technical change on per capita income. EK = GRM of total capital on per capita income. EL = GRM of total labor on per capita income.

A disturbing conclusion from figure 1 is the very low multiplier of capital. This is due to the low capital coefficients in the production function, particularly in agriculture. It is so low because agricultural capital does not include land, but the multiplier remains low even if land is treated as capital as in Yamaguchi and Binswanger.[9]

The multiplier of nonagricultural technical change is close to one and fairly constant. The agricultural multiplier declines over time as the size of the agricultural sector declines. The agricultural technical change multiplier is always smaller than the nonagricultural one, even at the beginning when both sectors are of about equal size. This reflects the fact that nonagricultural technical change transfers more resources to nonagriculture than agricultural technical change and that labor is more productive in nonagriculture due to the market imperfection.

In table 6, the multipliers have been multiplied by the actual rates of change of the exogenous variables. The contribution of nonag-

[9] To some extent this conclusion would be altered if technical change was largely capital embodied. It would then be incorrect to treat capital accumulation and technical change independently. To the extent that capital embodiment is more important in nonagriculture, this would tend to reduce the effectiveness of nonagricultural technical change.

Table 6. The Contribution of the Exogenous Variables to the Growth Rate of Real per Capita Income in Average Rate per Year

		Contribution of Growth Rate of:					
Decade	Observed Growth Rate	Agr. T.C. T_1	Nonagr. T.C. T_2	Capital K	Labor L	Population Q	$L + Q$
1880	6.25	2.37	7.78	0.39	1.52	−1.38	+0.14
1890	2.53	1.19	0.96	0.30	0.90	−1.43	−0.53
1900	0.13	1.21	−0.70	0.40	0.49	−1.60	−1.11
1910	3.51	2.29	3.02	0.81	0.34	−1.59	−1.25
1920	0.76	0.54	4.64	0.64	0.69	−1.79	−1.10
1930	2.41	1.48	1.45	0.89	0.77	−1.44	−0.67
1950	9.52	1.35	9.30	0.54	2.17	−1.44	+0.73
Average	3.58	1.46	3.78	0.57	0.98	−1.52	−0.54

ricultural technical change is the largest, on the average, because both the multiplier and the rate of technical change are largest for this variable. The contribution of agricultural technical change generally exceeds that of labor and capital as well. It is also less variable over time than the one of nonagricultural technical change. The contribution of the labor force growth exceeds that of capital, but the difference is smaller than the difference in multipliers. Population growth has, of course, a negative impact on per capita income growth. Indeed, if the contributions of labor growth and population growth are summed, the result is on the average small and negative. Hence, population and labor force growth combined had in Japan a small negative effect on per capita income, a result which agrees with Kelley and Williamson. But this benign assessment of the effect of population growth results only from the fact that the labor force participation rate did not drop. If it had dropped, as it might have in the case of much larger population growth rates, the picture could have been entirely different.

The distorted transformation curve of this model is very flat, as discussed before. The terms of trade are therefore almost totally governed by the sectoral technical changes. The GRM of T_1 and T_2 on the terms of trade were around -1 and $+1$ respectively throughout the period, while the GRM on the terms of trade K, L, and Q were around -0.1, $+0.1$, and -0.03 respectively. Therefore, changes in demand have almost no influence on terms of trade, but differential rates of technical change in the two sectors caused a turn of the terms of trade in favor of agriculture throughout the period (see table 5).

Table 7, columns 1–4, summarizes the output allocation effects of technical change. Technical change in each sector increases per capita income and decreases the price of the good which experiences the technical change. Hence, output and consumption of the good increase.

More interesting, however, are the cross effects; agricultural technical change tends to increase nonagricultural output, despite the rise in the relative price of the nonagricultural good. The income effect outweighs the price effect. Conversely, nonagricultural technical change tends to decrease consumption of agricultural commodities. Hence, in the Japanese case, the income elasticity of agricultural goods was not sufficient to outweigh the relative price increase of the agricultural goods due to the nonagricultural technical change. Also, as the size of the agricultural sector declines, the absolute size of the cross effects decreases.

Table 7 also shows the resource allocation effects of sectoral technical change. As above, technical change in nonagriculture pulls resources into that sector, despite the reduction in factor requirements to produce one unit of output. On the other hand, technical change in agriculture pushes resources out of that sector, which is an important observation for countries experiencing employment problems.

Summary and Implications

The main conclusions can briefly be summarized as follows. (*a*) Technical change in Japan has contributed more to growth than traditional factors, because the rates of technical change exceeded the rates of accumulation of the traditional factors. (*b*) Nonagricul-

Table 7. GRM of Sectoral Technical Change, Sectoral Outputs, and on the Allocation of Capital and Labor among Sectors in Average Percent per Year

Five-Year Span Beginning	Y_1T_1[a]	Y_1T_2[a]	Y_2T_1[b]	Y_2T_2[b]	K_1T_1[c]	K_1T_2[c]	L_1T_1[d]	L_1T_2[d]	K_2T_1[e]	K_2T_2[e]	L_2T_1[f]	L_2T_2[f]
1880	0.86	−0.25	0.51	1.93	−0.26	−0.48	−0.18	−0.33	0.45	0.82	0.54	0.98
1885	0.83	−0.20	0.48	1.55	−0.30	−0.35	−0.24	−0.27	0.44	0.50	0.50	0.57
1890	0.82	−0.22	0.44	1.53	−0.32	−0.34	−0.27	−0.32	0.40	0.48	0.45	0.55
1895	0.81	−0.23	0.41	1.48	−0.36	−0.42	−0.29	−0.34	0.36	0.42	0.43	0.50
1900	0.74	−0.25	0.37	1.44	−0.34	−0.47	−0.30	−0.36	0.31	0.37	0.40	0.48
1905	0.79	−0.27	0.34	1.43	−0.41	−0.52	−0.30	−0.39	0.27	0.34	0.37	0.47
1910	0.78	−0.28	0.32	1.41	−0.43	−0.55	−0.31	−0.39	0.23	0.30	0.36	0.46
1915	0.76	−0.26	0.31	1.33	−0.49	−0.53	−0.32	−0.35	0.20	0.22	0.36	0.39
1920	0.76	−0.22	0.27	1.26	−0.51	−0.48	−0.32	−0.30	0.14	0.13	0.33	0.31
1925	0.76	−0.22	0.25	1.22	−0.51	−0.45	−0.32	−0.28	0.12	0.11	0.31	0.27
1930	0.71	−0.28	0.26	1.25	−0.58	−0.55	−0.36	−0.35	0.11	0.10	0.32	0.31
1935	0.70	−0.29	0.24	1.23	−0.61	−0.60	−0.39	−0.39	0.10	0.10	0.31	0.31
1940	0.69	−0.27	0.23	1.21	−0.67	−0.59	−0.44	−0.39	−0.08	0.07	0.32	0.28
1945	0.74	−0.25	0.22	1.21	−0.58	−0.57	−0.36	−0.35	0.06	0.06	0.28	0.28
1950	0.72	−0.23	0.28	1.23	−0.64	−0.53	−0.39	−0.32	0.06	0.05	0.32	0.26
1955	0.71	−0.21	0.19	1.14	−0.52	−0.38	−0.35	−0.26	0.05	0.04	0.22	0.16
1960	0.68	−0.19	0.15	1.09	−0.56	−0.34	−0.43	−0.26	0.05	0.03	0.18	0.11
1965	0.66	−0.17	0.11	1.05	−0.52	−0.27	−0.42	−0.22	0.04	0.02	0.13	0.07

[a] GRM of agricultural and nonagricultural technical change on agricultural output.
[b] GRM of agricultural and nonagricultural technical change on nonagricultural output.
[c] GRM of agricultural and nonagricultural technical change on agricultural capital.
[d] GRM of agricultural and nonagricultural technical change on agricultural labor.
[e] GRM of agricultural and nonagricultural technical change on nonagricultural capital.
[f] GRM of agricultural and nonagricultural technical change on nonagricultural labor.

tural technical change has contributed more to per capita income growth than agricultural technical change, primarily because the agricultural technical change multiplier has been smaller than the nonagricultural one except for the period 1880–85 and because it has been steadily declining through time as the importance of that sector declined in the economy. (*c*) Terms of trade are primarily determined by sectoral technical change and not by demand forces because the transformation curve has very little curvature, but demand forces determine the output mix. (*d*) Technical change in agriculture tends to push resources out of agriculture, while nonagricultural technical change tends to draw resources into nonagriculture. The asymmetrical effect of technical change is due to the low price and income elasticities for agricultural commodities in a closed economy. (*e*) Population growth has a more detrimental effect on per capita income the smaller the nonagricultural sector out of which resources must be drawn for an increased food production.

To what extent do these conclusions reflect the restrictive assumptions of the approach used in this paper? The growth accounting conclusions (*a*), (*b*), and (*e*) are probably fairly robust with respect to changes in basic assumptions or parameters used in the model. Conclusion (*c*) on the flatness of the transformation curve deserves more caution because it derives quite directly from the assumption of Cobb-Douglas functions and of a labor market imperfection. It is probably unlikely that a transformation curve would be flat throughout its range and for very wide shifts in commodity mix. However, it may be quite realistic as a local approximation of the transformation curve in the neighborhood of the production point.

Conclusion (*d*) is the most controversial. It is due primarily to the low demand elasticities for agricultural commodities,[10] but these low elasticities of demand are well documented empirically. However, if the model was opened to international trade, the relevant price elasticity of agricultural demand would increase substantially. With such high demand elasticities, technical change in agriculture would not necessarily tend to push resources out of that sector. The additional international

[10] It is definitely not due to the assumption of a labor market imperfection. While the labor market imperfection affects the static solution of the model, i.e., the level of resource allocation among the sectors initially, it has very little effect on growth rates of the sectoral inputs as long as the exogenous wage differential does not change. Only changes in this differential would influence growth rates of the sectoral inputs.

demand generated by a reduction in agricultural prices due to the technical change may be sufficient to offset the reduced resource use on any given level of output and hence lead to expanding employment opportunities in agriculture.

Many of today's less developed countries have agricultural sectors as large or larger than Japan in the 1880s. In addition, they have larger population growth rates than Japan had at that time, which makes employment problems more difficult. And most of these countries now attempt to achieve growth via agricultural technical change. Clearly these countries cannot expect an agricultural sector which experiences rapid technical change to absorb vast amounts of additional labor, unless the agricultural sector is heavily export oriented. Recognizing this problem implies that the nonagricultural sector cannot be neglected. Unless this sector experiences growth and technical change, labor has nowhere to go and will only depress wage rates. What emerges out of the conclusions of this paper is a difficult balancing act between the sectors which is the more difficult the higher the population growth rates and the earlier the development stage.

Agriculture could, of course, absorb more labor if technical change was labor using rather than neutral. However, as discussed in footnote 4, technical change in Japanese agriculture was not labor using with respect to its own factor proportions in 1880. It is therefore unlikely that other less developed countries will be able to develop technology which is labor using with respect to their own present position. On the other hand, if they should decide on a course of borrowing technology from countries with highly capital-intensive technological paths, such as the United States, then agricultural technical change will result in even more labor displacement than predicted by our model. Therefore, there is a strong necessity to guide agricultural technical change according to factor endowments of each country as suggested by Hayami and Ruttan.

This research also brings back earlier concerns of the development literature with the transfer of resources from agriculture to the nonagricultural sector, as in the work of Lewis, and Fei and Ranis. There is a bonus to be gained from expanding the nonagricultural sector, but it is not in the form of a laborer without opportunity cost in agriculture who almost miraculously brings with him his own wage rate and food as he enters the nonagricultural sector. Such free surpluses do not exist here. Instead, growth is due to technical change in either sector or to capital accumulation. The resulting increases are spent primarily on nonagricultural goods. This permits the nonagricultural wage rate to rise sufficiently above the minimum differential to draw additional labor out of agriculture and capital as well.

The probably higher maintenance cost of a person in nonagriculture is reflected in the differential needed to induce him to migrate and stay in the nonagricultural sector. The economy pays for that in equilibrium by that wage differential; hence, the benefit from transfer is not free. Also, the dynamics are different. The system does not move primarily through capital accumulation in nonagriculture alone but through technical change in both sectors and through capital accumulation in both sectors. Artificially forced transfer of labor leads to no bonuses. The framework is closer to Colin Clark's framework which recognizes two sources of benefit: growth of output per worker in both sectors and transfer of labor to higher productivity sectors. Development policy in the 1950s chose to emphasize the transfer of labor rather than the growth of output per worker in both sectors, which was probably not intended initially in that kind of framework.

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Interest Rate Determination in Underdeveloped Rural Areas

Anthony Bottomley

Interest rates for rural and unorganized money markets in third world societies have not been extensively studied. This paper uses a comprehensive review of agricultural credit literature to explore the relationships between the costs of extending credit, amounts loaned, and the borrower's ability to absorb further capital. High costs in administering small loans and resistance to repay suggest the convenience of linkages between lending agencies and marketing boards for the crops upon which loans are made. Village moneylenders-cum-traders may be able to operate more efficiently than public agencies, particularly when trained staff are in short supply.

Key words: agricultural credit, interest rates, lending costs, loan defaults, risk premiums.

The price of money has enthralled economists in the richer nations of the world. The rate of interest has stood at the heart of most influential theories. By contrast, there has been relatively little analysis of this rate in the predominantly rural, unorganized money markets of the third world where most people probably live.

A framework for such analysis can be simple enough. It need only comprise an examination of the four components of rural interest rates: (*a*) the opportunity cost of the money involved, (*b*) the premium for administering the loan, (*c*) the premium for risk, and (*d*) monopoly profit (Bottomley 1963a, 1964a, 1972, 1964b, 1963b; Bottomley and Nudds).

The Opportunity Cost of Money

The pure rate of interest will be that rate which equates the supply of and demand for loanable funds, the supply of and demand for money to hold, or, if one follows Sir John Hicks, both of these simultaneously. The issues involved are covered with mounting thoroughness in succeeding generations of macroeconomic textbooks and need not detain us here. But postclassical theories of interest rate determination do imply that savings will be more a function of changes in national, or, in this case, rural incomes than of variations in the rate of interest per se, although there is some evidence that rural savings can be elastic with respect to the rate of interest (Adams, p. 169). However, it is often claimed that when the saver is himself the investing farmer, savings increase rapidly with the appearance of high rates of return. Many farmers in India have paid for purchases of new, high yielding wheat varieties out of their own resources (Shah) and the quantitative evidence shows that "credit availability has been on the borderline as a significant variable in the relationships to speed of adoption [of dwarf wheat] over the period 1960–1970" (Lowdermilk, p. 190). But any such high rates of return on capital are not easily transmitted from a borrower to a lender because, as we shall see, considerable premiums for administration and risk are likely to intervene.

Suffice it to say, then, that we assume a pure rate of interest here of 5% on our hypothetical lending cost structure in column 8 of table 1. By implication there is no expected inflation with this rate as a rational lender would also demand compensation for any expected decline in the purchasing power of the means of repayment. A pure rate which incorporated inflationary premiums would theoretically be above our 5% by whatever the expected rate of inflation was, although in practice negative real rates are not uncommon, particularly in Latin America.

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Table 1. Hypothetical Lending Cost Structure on Loans to a Representative Borrower with Constant Net Returns to Scale

		Moneylenders Cost ($)					Urban Banks Costs ($)				
Volume of Loans ($)	Borrower Net Income ($)	Basic Rate (%)	Average Adminis-tration Cost (%)	Default (%)	Overall Risk Premium (%)	Average Lending Cost (3 + 4 + 6) (%)	Pure Rate (%)	Average Adminis-tration Cost (%)	Default (%)	Average Risk Premium (%)	Average Lending Cost (8 + 9 + 11) (%)
1	2	3	4	5	6	7	8	9	10	11	12
100	200	15	20.00	10.00	15.00	50	5	40.00	27.50	55.00	100
200	400	15	10.00	9.42	13.00	38	5	20.00	26.47	45.00	70
300	600	15	6.67	7.83	10.33	32	5	13.33	21.11	31.67	50
400	800	15	5.00	6.25	8.00	28	5	10.00	14.81	20.00	35
500	1000	15	4.00	4.80	6.00	25	5	8.00	9.60	12.00	25
600	1200	15	3.33	4.65	5.77	24	5	6.67	6.94	8.33	20
700	1400	15	2.85	4.19	5.15	23	5	5.71	4.56	5.29	16
800	1600	15	2.50	3.69	4.50	22	5	5.00	2.65	3.00	13
900	1800	15	2.22	3.12	3.78	21	5	4.44	1.50	1.66	11
1000	2000	15	2.00	2.50	3.00	20	5	4.00	0.91	1.00	10

But whatever the pure rate may be, it does seem improbable that the opportunity cost of money will dominate any free market interest charge in underdeveloped rural areas. What this cost will actually be is hard to determine. It may be the value to a rural saver of parting with liquidity or of foregoing the opportunity to invest in his own farm or of fulfilling his social obligation to provide a lavish wedding for his daughter. Alternatively, it may be the pure 5% plus the administration and risk charges which a bank levies on an urban wholesaler who, in turn, relends with further levies on the transaction to the village shopkeeper who buys his goods.[1] If the shopkeeper is unable to synchronize his lending to a farmer with his borrowing from a wholesaler through this sale of goods, then the interest which he charges will have to compensate for the periods in which such money lies idle in the village shops. If, for example, a moneylender only lends for six months from sowing to harvest and his money lies idle in consequence for the rest of the year, then he must charge twice the annual rate on, say, government bonds for the duration of the loan in order to cover the opportunity cost of his money.[2] Thus, by the time the village shopkeeper comes to relend to peasant customers, the cost involved may have risen from its pure level of 5% in column 8 to a basic rate of 15% in column 3 of table 1. Unlike the other components of the rate of interest, these two elements are unlikely to vary as the volume of lending in column 1 increases.

All this does not imply that rural lending is entirely in the hands of merchants and shopkeepers. Larger landowners play a substantial role, as do relatives and friends.[3] The former will have a cost for their money which corresponds to opportunities foregone in terms of alternative investments or liquidity preference, and they will charge accordingly. Relatives and friends will also experience a sacrifice of these opportunities, but they are

[1] In fact, however, situations of this kind may not always predominate. *The All India Rural Credit Survey* (Reserve Bank of India, p. 178), for instance, reported that only 28% of the moneylenders interviewed expressed the need to try and obtain funds in addition to their own reserves.

[2] A rural credit survey in Chile revealed that "the most typical term was until harvest (from six to nine months) with 40% of loans carrying this term" (Nisbet 1966, p. 13). In Ecuador, it was 10.2 months (Agricultural Finance Center 1966a, p. 3). (See also Consortium for the Study of Nigerian Rural Development [1966b, pp. 7, 108] and Gapud [p. 80].) In Mauritius, "one shopkeeper estimated he was owed Rs. 500–600 per month during the inter-crop period, but only Rs. 100–200 during the crop season" (Benedict). In the Muda river area of Malaysia, pawnbrokers typically made loans for six to eight months, but usufruct mortgages against land were from one to three years (Wai and Hoover, p. 27). A premium for idleness of funds need not be considered when the lender prefers nonrepayment so that the borrower may be pressured into selling his crop through his creditor at below-market prices.

[3] Wolf Donner cites four studies in Thailand in which the source of credit to farmers originating with relatives and friends is 46%, 35% to 40%, 39%, and 57%, respectively. R. B. Morrow gives other farmers in South Korea as the source of 60% of private rural credit funds; 28% comes from relatives and friends, while the remaining 12% is provided by traders and moneylenders (Reserve Bank of India 1961–62). In Bangladesh, sources of credit were listed as 26% from relatives and friends and 53% from well-to-do rural people (Sobhan and Huq, p. 4). In Pakistan, 63% of rural credit was reported as coming from relatives and friends, 17% from well-to-do landlords, 13% from cooperatives and only 4% from shopkeepers and moneylenders (Lowdermilk, p. 271). In Sri Lanka, relatives and friends provided 26% of rural credit against 29% for moneylenders (Gunatilleke et al. 1973a, p. 221).

likely to be imputed rather than actually charged for, as interest is only rarely levied on these transactions.

The Administration Premium

It is reasonable to suppose that the village shopkeeper or landowner who lends to the small farmer places an opportunity cost on his time, even if he does no more than sacrifice leisure, as well as on any unavoidable souring of relationships which may occur between lender and borrower. We have valued these at $20 on a $100 loaned in the first row of column 4 in table 1, and such charges are not uncommon, particularly where public credit is intensively supervised (Adams, p. 168).

Exposition is simplified if we suppose that this so-called administration premium of $20 a year per loan to our representative borrower is a constant amount, regardless of the size of loan. The recording of a loan of $500 and the pursuing of the borrower at repayment time need not always be much more time consuming, arduous, or disagreeable than when $100 only changes hands, although if a given loan is for two years rather than one, then these charges would be less on an annual basis.[4] Thus, we assume in columns 4 and 9 of table 1 that when the size of a loan is doubled, the premium for administration on each $100 advanced is halved and so on through the range of lending volume recorded in the first column. But in practice, of course, it is likely that the larger loans will occasion more administrative effort, and the considerably higher charges for inspection visits levied by the Kenya Agricultural Finance Corporation on larger borrowers may be partially in recognition of this (Von Pischke 1973b, p. 49).

However, there is a presumed difference between the village shopkeeper or petty lender in the town and the urban bank. The formality of lending for an urban bank, involving as it does, buildings, paid clerks, and the like means that the administration premium on each unit loaned is higher in the organized than in the unorganized money market, as indeed it must be when banks safeguard other people's money.[5] Hence, in table 1, we assume a cost of lending for urban banks in column 9 which is consistently twice that, of, say, the village shopkeeper in column 4. The latter need not attribute all the cost of his shop or his time to loans which are incidental to his trade[6] and this differential seems likely to persist.

But administration costs on each unit loaned by a bank can be reduced by lending to groups of borrowers who distribute the loan among themselves. Cooperatives constitute such groups. In Thailand, for example, 90% of the state agricultural bank's administration costs were on its loans to individual borrowers and only 10% were on its loans to cooperatives. This was in spite of the fact that the latter obtained some 30% of the value of the bank's loans (Ingle, pp. 58–59). Although it remains true that where a cooperative has hired employees, this may be no more than a device for transferring administration costs on loans to them,[7] and in Kenya a government agency pays 1% commission on all cooperative remittances (Von Pischke 1973b, p. 25).

[4] In Ecuador, commercial banks make some unsecured short-term agricultural loans at interest rates of about 17%, with only 4% or 5% included for "recording, legal and appraisal fees . . . ." But these same banks sell bonds to the public at 10% a year and make long-term mortgage loans to farmers at 11% (Agricultural Finance Center 1966b, p. 8). One investigator, Fernando Diaz, estimated that in Peru a loan needed to be for at least $6000 before costs could be covered, whereas the average official farm loan was only $523 (Carranza, p. 51). In Brazil, the minimum figure was given at $2000 (Meyer, Adams, and Rask, p. 71). The Moroccan Agricultural Bank managed with an administration premium of 10% on loans of $200–$300, and it reported that this percentage decreased as the volume of the loan increased (Ulsaker, p. 142). But typical loans in agriculture do seem to be for much less than this. In Northern Nigeria, 43% of surveyed agricultural loans in 1958 were for less than $28 and 88% for less than $84 (H. S. Vigo, *Survey of Agricultural Credit Northern Nigeria 1958*, cited in Consortium for the Study of Nigerian Rural Development 1966a, pp. 8–9). In Uganda, the average size of loan to ordinary cooperative members in 1964–65 was around $20 (Hunt 1966, p. 5). In Equador in 1966, the mean size of surveyed private individual loans in agriculture was about $33 (Agricultural Finance Center 1966a, p. 3). A survey in Chile revealed that the same sort of debt per farmer was around $84 during 1964–66 (India, pp. 9, 17, 23). In Ceylon in 1960, the average size of cooperative short-term loans was only $28 (United Nations 1963, pp. 41, 43).

[5] In Mexico, before World War II, the National Bank found that its administration costs on rural loans were nearly 25% of the principal (Simpson, p. 389; see also pp. 399, 400). The Nigerian Western Region Finance Corporation said that it had to devote 47% of its revenues between 1958 and 1963 to covering administrative costs (Oluwasanmi and Alao). R. B. Morrow (p. 39) gives the administration costs for the Korean Government's Agricultural Bank at between 12% and 20%, depending upon what is included. In one part of Malaysia, administration costs on loans for padi production were in excess of 10% (Wai and Hoover). In Bangladesh, loans to cooperatives carried administration charges of 5% plus 1% commission for the cooperative's manager (Solaiman and Huq, p. 27). In Peru, the government's credit agency levies an administration charge of 6¼% on its loans (Tinnermeier and Dowswell, p. 6).

[6] Only 14 moneylenders of 613 questioned in India had no other occupation (Chandavarkar, p. 324).

[7] In Northern Nigeria, "local co-operatives pay 7½ per cent to banks . . . and charge farmers 15 per cent, regardless of the time element" (Johnson). In India, the difference between cooperative borrowing and relending rates used to be about 5% (United Nations 1965, p. 43). These differences between cooperative borrowing and relending rates will, of course, include premiums for risk as well as for administration.

The Premium for Risk

The foregoing simplicity of argument is much eroded when it comes to the premium for risk. To begin with, although we here illustrate a situation in which default is outright for the sake of simplicity, most cases are probably less clear-cut; payments are delayed, only partial payments are received, renegotiation is requested, and so on. Then too, the percentage charge on each unit loaned arises from, but is not the same as, the percentage of default. This is illustrated by the relationship between columns 5 and 6 in row 1 of table 1.

If \$100 is loaned and a net 10% of borrowers in this class are in default (i.e., current defaulters minus past defaulters who now repay in column 5), then the 90% who do repay on time will need to pay a risk premium of \$15 per \$100 borrowed, or 15% in column 6, not 10%. This is because the lender parts with a principle of \$100, of which only \$90 (\$100 − [\$100 × 10%]) is repaid on average, and incurs basic rate plus administrative costs in columns 3 and 4 of \$35. Of this \$35, only \$31.50 is recovered (\$35 − [\$35 × 10% default]). Thus, for every \$100 which he lends, \$13.50 (\$10 + \$3.50) is lost to the village moneylender through default on the principal plus the opportunity cost of earnings or leisure foregone during the period involved. The question then arises as to what this opportunity cost is as a proportion of the amount actually repaid and the answer is $\frac{\$13.50}{\$90}$ or 15%. The appropriate formula is then:

$$\text{risk} = \frac{\text{default rate} \times (\text{principal} + \text{lending costs})}{\text{principle actually repaid.}}$$

Thus, when the basic rate plus administrative costs are \$35 per \$100 loaned, a default rate of 10% requires that the lender levy a risk premium of 15% of the principal on each unit loaned. This means that the cost to a moneylender of supplying \$100 worth of credit is \$15 basic plus \$20 administration premium plus \$15 risk in columns 3, 4, and 6 of table 1. Hence, this particular moneylender cannot cover his costs unless he charges an annual interest rate of \$50 on a \$100 loan or 50% to individual borrowers of the type depicted here.

This, however, is by no means the end of the inquiry into the intricacies of the premium for risk. As yet we have done no more than establish the mechanical relationship between default and risk. But what causes default? That is the real question and we may try to answer it by a discussion of nine distinct considerations.

Volume of the Loan

The volume of the loan will affect default because, other things being equal, the more a man borrows, the larger will be the probability of his being unable to repay. The default rate is thus a positive function of the volume of the loan if the latter is taken in isolation.

Borrower Net Income

There appears to be a systematic tendency for larger farmers with greater asset values and higher incomes to borrow more than smaller, poorer farmers throughout the third world and, if their net incomes increase more rapidly than the cost of borrowing (MVP > MC), then their ability to repay as opposed to their willingness to repay will automatically increase (Bottomley and Nudds). Therefore, there will often be a correlation between increases in borrower net income and levels of repayment, although this correlation is not always as great as one might expect (Von Pischke 1974, pp. 109, 158, 1973a, pp. 65–66). Nevertheless, we do assume that rates of default in columns 5 and 10 of table 1 decline as the volume of borrowing and associated net income grows in columns 1 and 2. But there are a number of other considerations which bear upon default and which are dealt with under the headings which ensue. It must therefore be remembered that declining default rates in table 1 are predicated upon increasing ability to repay with unwillingness to repay remaining a major issue which is not contained therein.

But it does seem as if there is generally a positive association between the volume of a borrower's loans and the size of his gross income. In the United States, where farmer incomes are high, the credit income ratio in 1968 was 0.53, and in Taiwan, where they were also high by the standards of poorer countries, they were 0.39. In some of the higher income Latin American countries, the rate was equal to or greater than 0.50, while in many of the poorer ones, it fell below 0.15 in 1967 or 1968 (Adams, pp. 164–65). We cannot be sure, however, that default has necessarily de-

creased as borrower incomes have risen in Latin America. The U.S. Agency for International Development, the International Bank for Reconstruction and Development, and other aid agencies pumped more than $1 billion into Latin American rural credit programs during the 1960s. Between 1960 and 1967–68, the average credit income ratio for eighteen countries rose from 0.235 to 0.360 (Adams, pp. 163, 170), and it may well be that such massive infusions of credit encountered increasing rather than decreasing default in those countries where the interest rate was above the inflation rate.

In general, however, the evidence does seem to support the proposition embodied in table 1 that as borrower incomes and assets grow, rates of interest charged decline, although reductions in the other premiums, apart from risk, no doubt also play a part in this. In Costa Rica, for example, while moneylenders levied interest rates of between 18% and 36%, "very large" farmers managed to obtain credit from finance companies at between 12% and 24% (Brown, p. 22). In the Philippines, a credit survey revealed that where the average ratio of gross farm receipts to debt was 3.40 to 1, as it was with part owners of land, the average annual rate of interest was 40% a year, but it was 61% for tenants where this ratio was 1.90 to 1 (Gapud, pp. 79–80). Another survey (Nisbet 1967, pp. 17, 23) of 200 Chilean farmers during 1965 revealed that the typical individual farmer debt in the informal, village money market was around $84 (in U.S. dollars), while it rose to $284 for those who managed to borrow in the predominantly urban, institutional market. Interest rates in the latter were around a fifth of those in the former, and there was a strong correlation between the size of farmer income and access to the urban banks, although lower administration charges may also have played some part in this. In Korea, 1,000,000 farmers borrowed an average of $227 each from the state, while only 100,000 managed to borrow from the commercial banks where they obtained $900 on average in 1971 (Morrow, p. 38). Moreover, where farmers are in fact adopting new technologies or types of output with increased loans, the effect upon income often acts in more than a compensating way where default is concerned. In Mexico, for instance, loans were granted for the construction of poultry houses beginning in 1956 (United Nations 1964, p. 76); farmers practically doubled their incomes and repayment rates were close to 100%. A similar scheme in India showed substantial production gains with repayments of 87% to 90% on medium- and short-term loans respectively and 100% on longer-term advances (United Nations 1964, pp. 76–77, 79, 82). In Costa Rica, borrower net worth increased by $1.74 to $2.54 for every dollar borrowed from the government's *Junta Rural* credit program (Brown, p. 44). These same loans rose on average from $48 in 1937 to $582 in 1971. By then, the default rate was only 2.5%. In Morocco, defaults on loans of $20 to $60 were some 40% for one government lending organization, while for another, with average loans of $200 to $300, the default rate was less than 5% (Ulsaker, p. 142).

However, the expectation that total default will decline in columns 5 and 10 of table 1 as net income grows in column 2 is predicated upon the assumption that the borrower expects to try to repay a loan. If he does not, and often he does not, the picture will be entirely different. Government loans, as opposed to commercial ones, are particularly susceptible to this malaise. Where willful delinquency is tolerated, default may be just as common among those with high incomes as those with low. Indeed, the relatively well-to-do may use their local political power to persist with their default even when the poor cannot (Von Pischke 1973b, p. 31). In Sri Lanka, for instance, the percentage default on government loans in agriculture was only 5.6% on monthly borrower incomes of 61 rupees, in spite of the fact that the average loan was 55% of this amount, while it rose to 47% on loans to borrowers with monthly incomes of 113 rupees, of which the average loan represented only 21%. However, the default rate did fall again to 2.6% as borrower incomes rose to the relatively very high level of 5,272 rupees on average (Guntilleke et al. 1973a, pp. 76, 78, 81). In Colombia, recorded delinquency rates for agricultural lending by the state were roughly the same for small, medium, and large farmers at around 18% (Schwinden, pp. 44, 77). But, in Kenya, default rates on government agricultural loans did fall from 50% on small loans to 25% on large ones (Donaldson, pp. 16a, 57a, 61a, 66a).

Debt-Equity Ratio

The debt-equity ratio will probably be lower for high income farmers than for low income

farmers, even though the better-off farmer may borrow more in total. At all events, it certainly seems that the lower the ratio of debt to equity the lower the risk to the lender and the lower the interest rate which the borrower will probably pay, although the risk premium alone will not account for the entire difference. In Pakistan, for example, a survey of 350 farmers showed that those with holdings of between 2.5 and 7.5 acres obtained less than 2% of their loans from the low interest banks and credit societies as opposed to 6.5% from the moneylenders, but for those with holdings of more than 50 acres, loans from banks and credit societies rose to 37% of the total amount borrowed (Lowdermilk, p. 273).

The *All India Rural Debt and Investment Survey of 1961–62* (Reserve Bank of India) showed that large farmers with assets of 20,000 rupees or more and holdings of over 25 acres borrowed twice as much as small farmers with assets of between 2,500 and 5,000 rupees and holdings of about 5 acres each, giving rise to a presumably less risky, lower debt-equity ratio for the larger borrowers. The same was true of a sampling of borrowers in Kenya (Von Pischke 1974, p. 73). But in Brazil in 1965, farms of no more than 30 hectares obtained credit equal to less than one-fifth of their total output, whereas farmers with the "largest" holdings borrowed amounts equal to 47% (Meyer, Adams, and Rask, p. 75). In Peru, the size of loans was directly correlated with the size of borrower land holdings (Carranza, p. 33), and although we do not know how these asset holdings varied with net income, it would be surprising if the relationship was not direct and if lenders did not, in consequence, feel able to offer loans with a lower premium for risk.

Value of Collateral

The value of the collateral which can be offered will normally be greater for the higher income, higher asset farmer. In other words, it will bear upon default in much the same way as the debt-equity ratio. As borrower income rises, we would normally expect the debt-equity ratio to fall and the value of any collateral offered against a loan to rise. These three considerations, acting separately or together, lie behind the assumption of an inverse relationship between borrower income in column 2 of table 1 and default rates in columns 5 and 10.

As one might suppose, then, a number of instances of lower interest rates on secured loans can be cited. In South Vietnam, moneylenders charged 3% to 4% a month on secured loans against 5% on those which were unsecured (Sansom, p. 121). In the Philippines, landowners with a ratio of fixed, mortgageable assets to debt of 15.7 to 1 paid 15% a year less for their loans than tenant farmers with a 1 to 1 ratio (Gapud, pp. 79, 81). Indigenous bankers in India used to charge between 6% and 18% annually on secured loans "according to the nature of the security," while they normally demanded between 18% and 37.5% on unsecured loans "according to the standing of the borrowers." In general "loans properly secured by ornaments, land or other property, carr[ied] the lowest rate of interest" (Panandikar, pp. 57, 75).

But property is not the only form of collateral. Crops in the process of maturing can be used to secure a loan, but they are not always effective in this respect. In the Muda river padi area of Malaysia, future crop mortgages were accompanied by interest rates of 133% to 200% a year from the moneylenders. Problems arose with disputes over price as well as reductions for the dirt and moisture content of the rice bags. There was also a 10% loss annually through insect action and this was expected to increase with double-cropping (Wai and Hoover, p. 27). In South Vietnam, too, repayment in wet padi cost the lender anything up to an estimated one-third of his interest charge (Barton, p. 34). By contrast, the pawning of jewelry attracted an interest rate of only 24% to 36%, while loans against property, usually a buffalo licence, were made at from 40% to 60% a year (Wai and Hoover, p. 27). In Kenya, however, default was almost nil on government loans to cooperatives where their crops of tea and pyrethrum were marketed through statutory organizations (Donald, pp. 18–19; Von Pischke 1973a, p. 4).

But in general the provision of security will not be an important feature of lending in the unorganized money market. In India and Nigeria, for example, an estimated four-fifths of debt owed to professional and agriculturist moneylenders was unsecured (Chandavarkar; Consortium 1966b, p. 13). In Ecuador, 85% of individual moneylenders surveyed in 1966 required only a personal signature (Agricultural Finance Center 1966a, p. 3). Borrowers in poor countries either have no security to offer against a loan or foreclosure

may be socially, politically, or legally difficult. In Indonesia, for example, most of the moneylenders are Arabs or Chinese, and being aliens they cannot obtain a mortgage against private land (Metcalfe, p. 30).

Defaulters Brought to Court

The percentage of defaulters brought successfully to court will, of course, have considerable bearing upon the kind of willful default described above. Strict repayment discipline must be established early on in any rural credit program if default is to be kept within manageable limits and/or borrowers are to graduate to the low cost, urban commercial money market. This last is important if a government wishes to maximize the impact of limited official loan funds by using them only long enough for one group of borrowers to establish repayment records which will be satisfactory to an urban bank. Such graduation is unlikely to occur when, as in Bolivia, of the funds for agriculture discounted by the Central Bank, the two government credit agencies showed amounts equal to 55% and 41% of loans outstanding still to be repaid, as against only 4.5% for the private banks (Royden, p. 40).

The problem is that governments often have neither the resources nor the will to enforce repayment. In Thailand, for example, the government's agricultural bank had more than 14,000 borrowers in default, but only sixty-four of these had been brought to court. Under this kind of discipline, default rose more than thirtyfold between 1968 and 1971 (Ingle et al., p. 57).

Evidence of increasing delinquency on loans as borrowers come to realize that a particular government credit agency need not be repaid is rife. In Turkey, the default rate on agricultural credit is already 37% and appears to be getting worse (Stickley and Satana, pp. 1, 18). In Sri Lanka, overdue loans rose from 9% of those outstanding in 1963 to 16% in 1969 on the government's agricultural credit scheme (Guntilleke et al. 1973a, p. 217). In Jordan, default on government agricultural loans started very high at 77% in 1966, and the scope for subsequent increases in default was much reduced. Nevertheless, delinquency had managed to reach 81% by 1971. In Bangladesh, default rates rose in seven years from about 1% on official cooperative loans to 28% by December of 1967 (Stickley and Hayer, pp. 2, 30). They ultimately reached a grand total of 83% during the war of independence (Myers, p. 9).[8]

Thus, government credit is particularly prone to high rates of default in the absence of determined efforts to bring delinquents to book.

Income Variance

Variance around mean borrower income may be a major cause of inability to repay, and it may well get larger in absolute terms as borrower income grows, unless improved irrigation, flood prevention, storage, and/or disease, pest, or insect control provide sufficiently countervailing influences.

Variance is of two kinds where credit risk is concerned. It may comprise the revenue distribution around a mean borrower income in any given year, or it may arise from variations in that mean from one year to another due to natural disasters, plant disease, price declines, or whatever.

In this paper we generally argue in favor of using credit in support of productive innovation if high premiums for risk are to be avoided. But innovation per se will not necessarily reduce variance around mean income. In India, the new cereal varieties have either proved extremely profitable or extremely unprofitable. Yields have shown high variance. Of forty-three cases of such innovation examined recently, only two showed returns on the capital of between 0% and 50%. The rest were either above or below this return (Schluter, p. 27). In Sri Lanka, loan recoveries on the financing of the growing of risky chillies and onions were less than half those on the relatively riskless potatoes and vegetables, and 33% of agricultural borrowers

[8] However, somewhat lower rates of default than these on official credit were given in the *Spring Review of Small Farm Credit* for Colombia's *Caja Agraria* at 15% (Donald, p. 15), Malaysia at 14% (Wai and Hoover, p. 36), and Iran at 35% (Wai, p. 16). In prewar Mexico, the National Bank managed to recover only 32% of its rural loans in one particular year (Simpson, p. 389). Conditions appear to be as bad in Kenya and Nigeria where default on government credit in excess of 50% is not unusual (Von Pischke 1973b, p. 30; Consortium for the Study of Nigerian Rural Development 1966b, pp. 216, 293, 316–20, 323, 326, 330, 342). Nor is the introduction of a profitable innovation sufficient guarantee of willingness to repay. In Northern Nigeria, the "Ministry of Agriculture experimented with credit sales of fertilizer at full and subsidised prices, but had to abandon it in 1966 due to lack of repayment" (Consortium for the Study of Nigerian Rural Development 1966b, p. 167). The same is widely true of Uganda (Hunt n.d., pp. 8, 11, 14). But in Ecuador, the government's *Banco de Fomento* had experienced only a 2.65% default on its loans between 1948 and 1965 (Roth and Goodall, p. 15).

gave crop failure as the cause of their default (Guntilleke et al. 1973a, p. 80, 1973b). In Korea, too, half of the delinquency in the banking sector's loans to agriculture were on what were described as new, relatively risky enterprises. Default was a good deal less on such established crops as rice and barley (Morrow, p. 36). But even with rice, credit officers in Thailand state that "farmers can expect to lose their crop once every five years" (Ingle et al., p. 70).

In Southern Brazil, variance around mean crop-yield doubled as farmer output doubled (Rask, p. 57), and on one project in Kenya defaulters not only had systematically lower than average mean yields, but the variance around these means was greater than for those who repaid (Weisel, pp. 18, 19, 23). In such circumstances, a monopoly lender might charge different rates to different borrowers, but whatever he does, default will be a positive function of variance.

Loan Administration Costs

The cost of administering the loan may have some bearing on the rate of default. Time spent on pursuing defaulters costs money, and at least two governmentally inspired credit schemes think that it is not worthwhile (Hunt n.d., p. 80). Then, too, it is sometimes argued that steps to ensure that borrowers use their loans for productive purposes will likewise reduce the risk of inability to repay.[9] However, this is open to debate. Some believe that if a farmer sees the point of adding fertilizer, he will use whatever credit he can lay his hands on to this end whether he is supervised or not. But be that as it may, in Pakistan 34% more nitrogen is reported to have been used by those who had access to "sufficient" credit than by those who had not during the adoption of dwarf wheat varieties (Lowdermilk, p. 267). Colombian supervised credit did show increased production of 2 pesos for every additional peso of borrowed funds (Whitaker, Riordan, and Walker, pp. 15–16), and in Nepal the delinquency rate on a "heavily supervised" credit scheme was only 5% (Donald, p. 10).

Real Interest Rates

The real rate of interest on a loan will be the money rate minus the rate of inflation. Nothing can be relied upon to reduce default more than a low money rate of interest coupled with a high rate of price increase. After all, if the government lends at 10% during a period when the cost of living rises by 60%, then it is paying the borrower 50% to take its credit. In two years it has given the original principal away in real terms and, providing the borrower repays, he can expect such gifts to continue. To default and cut off this source of credit is tantamount to killing the goose that lays the golden egg. That is why it is scarcely surprising that the *Associacao de Credito e Assistancia Rural* in Brazil was able to boast of a repayment rate of 99.7% (Viera n.d., p. 38). With Brazilian inflation customarily running at between 20% and 90% a year and interest and commissions on official loans no more than 18% (Meyer, Adams, and Rask, p. 61), it is only surprising that 0.3% did, in fact, default. Perhaps they were trodden under foot in the stampede to repay.

The relatively low default rate of 11% on official agricultural credit in Korea, too, may have had something to do with the fact that inflation over the period in question was 9% a year against an interest rate of 8.6% (Morrow, pp. 33, 67). But it is always possible that inflation rates may differ between sectors and, by moving the terms of trade against agriculture, make default more, rather than less, likely.

The Lender

The type of lender who makes the loan will vary and the premium for risk will vary accordingly. Although default will increase or decrease as it is influenced by the above factors, the degree to which they will affect delinquency will depend upon whether the lender is a village moneylender, an urban commercial bank, a cooperative, or another type of governmental credit agency. There is probably a tendency for default to increase as we move from the first to the last on this list. It seems likely that the village moneylender will have the lowest default rate on small loans. He knows the character and repayment

[9] It appears that in India, Nigeria, and Chile, for example, at least half of the total rural borrowing is for family expenditures (Reserve Bank of India 1955, pp. 6, 219, 220; Nisbet 1966, p. 14). Ingle et al. (p. 71) cite three separate studies for Thailand in which borrowing for consumption in rural areas ranges from 40% to 60% of the total. It might be assumed that borrowing for consumption purposes would increase default since increased production would not result from the loan. But in practice a farmer may borrow to feed his family in one part of the year and use his postharvest surplus for investment in another.

capabilities of his clients at firsthand and he can fix would-be defaulters with a beady stare every day of their lives, or, *in extremis*, arrange for them to be beaten up (Rask, p. 483). This is why we assume in column 10 of table 1 that the default rate for an urban bank will be initially a good deal higher than that of the moneylender in column 5, although local moneylenders do sometimes lose quite heavily.

It is sometimes argued that extending official credit to cooperatives constitutes a device for reducing default on official credit since they duplicate many of the advantages of the local moneylender. After all, the whole membership of the cooperative can be made responsible for an individual's default. Social coercion to repay can thus be just as strong within the cooperative's locality as it is for the village moneylender. But if the government remains unwilling to treat the entire membership strictly, then the group as a whole will default to the extent that its individual members do not repay. The Sudan's agricultural bank, for example, found that the default rate on its loans to cooperatives was 45% as against only 13% on its loans to individual farmers (Stickley and Hamid, p. 129). Default on cooperative lending in Thailand, too, was 38% of loans outstanding in spite of the fact that borrowers were of above average farm size and prosperity and that loans were held against an expected 70% of the market value of the borrower's crops (Ingle et al., pp. 5, 39, 46). The same default rate of 38% on cooperative loans was also reported for India in 1970 (India, pp. 6, 45). In Peru, cooperatives had the doubtful privilege of being able to report that they had only to reschedule "54 per cent of their loans against 77 per cent for individual small farmers on Government loans" (Carranza, p. 49).

The situation is not always so, however. During the three years 1962–63 to 1964–65, loans through the Co-Operative Division of the Northern Nigerian Government had repayment records of 92%, 83%, and 88%, respectively. In Eastern Nigeria, the registrar estimated that government loans through cooperative societies had overall default rates of only 3%, but agricultural loans alone had a higher rate of default than this average. In Western Nigeria, repayment on loans through three cooperatives from 1955–56 to 1965–66 averaged 72%, 90%, and 104% (including some repayment on loans made prior to 1955) for the period (Consortium for the Study of Nigerian Rural Development 1966b, pp. 216, 293, 316–20, 323). Similar relatively low default rates have been recorded in Uganda (Hunt 1966, pp. 7, 87).

Yet cooperatives remain notoriously difficult to form. In India prior to 1960, they only furnished 3% of the nation's rural credit after some fifty years of effort in the field. However, the rate of expansion for such societies is now growing (United Nations 1965, pp. 55, 63) but not, one hopes, as a consequence of the permitted rate of default mentioned above.

Finally, with respect to cooperative credit, it should be mentioned that there is a widespread tendency for the relatively well off, who form the local management committees, to take more than their share of the loans granted. In Bangladesh, they reportedly took 65% (Myers, p. 10). Thus, few things are clear-cut in the rural credit field.

Monopoly Profit

This has traditionally been adduced as the major cause of high interest rates in underdeveloped rural areas and no doubt it often occurs. Theoretically, a monopolist will lend up to that volume at which his marginal lending costs equal the value of the borrower's marginal product on the loan and he will levy a rate of interest equal to this value of the marginal product where produce markets are competitive (Bottomley 1971). But, as has been pointed out, investigators should not be misled by interest rates which do not appear to equal the value of marginal products. The true rate is often subsumed under the price at which the village trader sells his goods to the farmer or artisan and the price at which he buys his borrower's output where such transactions are associated with the loan. Indeed, loans are characteristically so used primarily to facilitate trade. (See, for example, Ayyer and Ramanswami, p. 24; International Labor Office, p. 95; Wai, pp. 98–99; Wharton.)[10] It should not be assumed, however, that they are necessarily usurious as a result. In general, it

[10] In Ecuador, 21 out of 151 private moneylenders surveyed in 1966 admitted to levying interest by "decreas[ing] the price of the product under which the farmer borrower was obligated to sell to the lender" (Agricultural Finance Center 1966b, p. 3). It is claimed that in Gambia, the Sudan, and Sierra Leone, traders get between 50% and 300% on a loan in this way (United Nations 1963, pp. 30–31).

seems likely that a borrower will welcome credit and a lender will be happy to extend it in order to ensure that farmers, for example, will sell their crops through him. Indeed, many lenders claim that they would prefer not to extend credit at all if they could be sure of a steady supply of farmer output in which to trade. (See, for example, Agricultural Finance Center 1966a, p. 3.)[11] But, of course, this may mean no more than that they do not wish to engage in competitive bidding for such output and that they claim their usury in the form of the lower-than-auction prices at which they can buy from their borrowers.

We can say, then, that at low lending volumes and associated low income levels, the village moneylender probably has the competitive advantage vis-à-vis all other lenders. But from our discussion of the probable association between increases in the volume of loans and higher net borrower income with associated reduction in the debt-equity ratio and increases in the value of collateral, it does seem that private urban banks can break this moneylender's monopoly in the higher income ranges. This point is illustrated hypothetically in table 1 at a level for individual loans of $500 and an interest rate of 25%. Here the urban bank's 10% advantage in pure rates between columns 3 and 8 compensates for its 10% disadvantage in administration and risk premiums vis-à-vis the village moneylender in columns 9 and 11. The urban bank can thus tolerate a default rate in column 10 at 9.6% of a $500 principal, which is twice that of the village moneylender in column 5. Thereafter, the bank's advantage becomes more marked. But the establishment of such a relative advantage may take time. If a small borrower with a low income quickly becomes a large borrower with high income due to the adoption of dwarf wheat or whatever, his attitude towards and relationship with an urban bank may not change quite so rapidly. There are doubtless intangibles borne of repayment disciplines established long ago, perhaps even many generations previously, when the larger borrower adjusted to repaying his distant bank creditor in the town. The newly rich might not accomplish this transition in a year or two.

Moreover, table 1 depicts a money lending cost alone, including any real interest which a moneylender may obtain through trading in the borrower's produce at the advantageous prices which their credit relationship may allow. But there are certain to be shadow charges for the smaller farmer in dealing with an urban bank. The cost and time taken to journey to a town, the difficulty of filling in a form, the forbidding superiority of the bank officials, the inflexibility of repayment dates and rescheduling procedures may all make the urban bank's loan appear more costly than the actual money charged to the peasant farmer.[12] Thus, the declining average lending cost in column 12 of table 1 represents the bank's potential for entering the rural money market in competition with the village moneylender in column 7 beyond $500 loaned per borrower. But this does not mean that such a potential will always be realized. The shadow cost of bank loans to the village borrower may be above that given in column 12 of table 1. But if we accept it as it is, then the bank will enter into competition with the village moneylender at a loan volume of $500 and an interest rate of 25%. Any monopoly profit which may have accrued to the latter will then disappear, although this will not ensure us against the possibility of monopolistic practices on the part of the urban banks.

Conclusions

We have tried to show that administration costs per unit loaned should decline as more is borrowed by individuals for longer periods and that this is really a function of the borrower's ability to absorb further capital investment at sufficiently high marginal rates of

[11] A survey in Lebanon showed traders losing 6% on loans at 10%. But they argued that the gain to them was in the trade itself. Moneylenders in general apparently made only 4% monopoly profit on loans to farmers at 16% interest (Stickley, Mouracade, and Yashshu, p. 4).

[12] A survey in Ecuador in 1966 revealed that 30% of rural borrowers favored prompt credit supply over lower cost; yet 56% did purport to favor lower cost (Agricultural Finance Center 1966a, p. 24). But the Ecuadorian Development Bank does admit to taking from 16 to 70 days to process a loan (Fryer, Hayes, and Benalcazar, p. 15). To end March 1966, over 3,000 application forms had been sent to applicants for loans by the Eastern Nigerian Fund for Agricultural and Industrial Development, but only 1,400 had been completed and returned (47%), showing probably that many applicants had found the form too complicated for them (Consortium for the Study of Nigerian Rural Development 1966b, p. 301). The various aspects of the Jordanian Government's agricultural lending program which farmers found dissatisfying are fairly typical of issues affecting shadow interest rates on public loans. These aspects of the lending program and the percentage of farmers expressing dissatisfaction with them are as follows: (*a*) control over purpose for which the loan was given—75%, (*b*) security requirements—63%, (*c*) interest charged—55%, (*d*) difficulty of obtaining more than one loan—54%, (*e*) amount of the loan—52%, (*f*) difficulty of renewing the loan—49%, (*g*) failure of repayment dates to coincide with harvest dates—75%, (*h*) waiting time before loan was granted—33%, (*i*) distance of journey to bank office—29%, and (*j*) duration of the loan—22% (Stickley and Hayer, p. 64).

return to cover lending costs. We have also argued that the premium for risk is very much a function of the difference between these additional returns and basic costs (pure and administration premiums on loans). If borrowers are able to repay, then that is half the battle. But they may well remain unwilling to repay unless they are forced to do so. Governments must be prepared to encourage and support their credit agents in foreclosure. Failing that, they should normally ensure that a lending agency controls the marketing of the crops upon which loans are made so that they may be recovered from the sales.

Yet even where these things are done, the expense of lending small amounts to farmers who resist repayment to the last will still be high in administrative terms, particularly where trained staff are in short supply. If the village moneylender-cum-trader can undercut this, taking into account any lower prices which he may pay for a borrower's crop, then so be it. Let him continue to provide the necessary finance. Other ways can be found of helping the rural dweller. There is no apparent reason why a government should transfer income to farmers in the random manner which widespread default allows or through charging rates of interest which fail to cover costs.[13] It is true, however, that rural areas are very much prone to the exigencies of the economics of the "second best." Workers leave the countryside to queue for higher wages in the town and their marginal productivity on the farm is lost. But it seems unlikely that subsidizing rural lending charges would be a prime candidate for correcting this in any rational examination of alternative policies. No, if farmers see that credit has really productive uses, then they will usually want to borrow. They will be able to repay principal plus costs and they should be made to do so. No more credit should be offered to underwrite the status quo.

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[13] Some sixteen years ago, U. Tun Wai estimated what he called a worldwide weighted average interest rate of between 24% and 36% for private rural lending in underdeveloped countries (p. 123). Ingle et al. (p. 41) gave a figure of 29% for Thailand; Morrow (p. 29) gives one of 60% for Korea, but this figure would be less if inflation rates were deducted. Carranza (p. 56) gives the rural rate at between 8% and 10% per month for Peru, while 33% is the most frequently quoted rate for Afghanistan (Norvell, pp. 181–82). By contrast, the interest rates on rural credit extended by the government agencies reported on in the *Spring Review of Small Farm Credit* is most commonly in the 6% to 8% range (Donald, p. 11).

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Analysis of Aggregation Errors in Linear Programming Planning Models

Alvin C. Egbert and Hyung M. Kim

An analysis was made of errors which can result from regional aggregation in spatial linear programming models. The agricultural sector of Portugal provided the empirical base for the analysis. Programming solutions were obtained first for eleven regions and then for three regions which were aggregates of the eleven regions. It is concluded that significant errors which resulted from this form of aggregation can be reduced or eliminated by intraregional stratification of production activities and resources and a priori specification of intraregional transport cost.

Key words: aggregation errors, linear programming, Portugal, planning.

In the late 1940s, a flurry of articles appeared on aggregation errors in systems of simultaneous equations (Klein 1946a, 1946b; May 1946, 1947; Pu). This interest seemed to reach an apex with Professor Theil's book, *Linear Aggregation of Economic Relations*. More recently, other studies have dealt with aggregation errors in various types of economic models (L. M. Day; Fromm and Schink; Green; Grunfeld and Griliches; Gupta; Herdt; Mo).

In the early 1960s, R. Day, Frick and Andrews, Sheely and McAlexander, Miller, and Lee analyzed aggregation errors in linear programming models. Day, Miller, and Lee analyzed the conditions under which producers could be aggregated without error. Frick and Andrews's and Sheehy and McAlexander's articles dealt with errors in linear programming "supply functions" resulting from different methods of aggregation. None of these analyses explicitly considered the problem of aggregation over space, although it was implicit in their procedures.

This paper reports the results of an investigation of aggregation errors in spatial equilibrium programming models. The agricultural sector of Portugal provided the empirical basis for analysis. The objective was to determine how the programming results change when a larger set of economic data and relationships are aggregated and represented by a smaller set. The frame of reference for aggregation was their location in space. For this operation, contiguous microregions were combined to form macroregions. If the macro- and micromodel results are always the same or nearly so, then it is necessary and sufficient to do only macroanalysis, except in the case where the planner wants to know the exact location for a dam, a processing plant, or other type of development investment. Obviously, only microregional analysis can give such specifications.

It is assumed that the relevant planning model is the classical spatial equilibrium type as defined by Samuelson. The planner's objective is to determine a plan such that marginal costs are equal to marginal benefits for all products and all regional markets. Considering only one product in one region, this is equivalent to a planning goal of maximizing total producer and consumer surplus as defined in figure 1.

The triangle PCD represents the consumer's surplus which is the difference between the marginal value of each succeeding unit, as expressed by the demand curve DD_1 and what consumers must pay for a commodity, price P. Similarly, the producer's surplus, represented by triangle PCS is the difference between the price received for the product and the mar-

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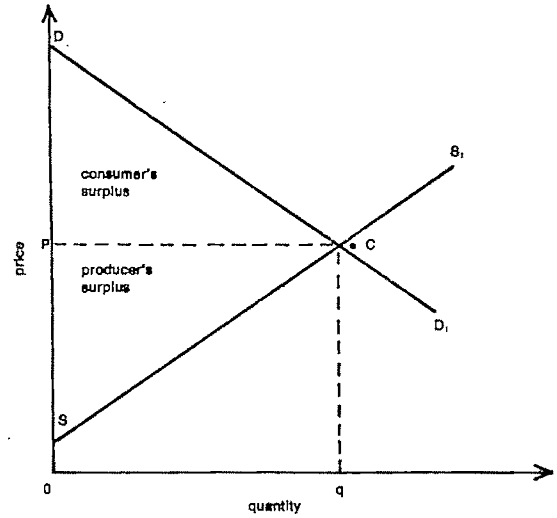

Figure 1. Producer's and consumer's surplus in market equilibrium

ginal production cost of each succeeding unit which is expressed by supply curve SS_1.

Supply curves in the analysis are step functions and can only be graphed *a posteriori* because the nature of the supply curve is only determined in the final equilibrium solution. In figure 1, this means that the supply curve SS_1 which is determined by marginal unit cost may take different shapes and levels from solution to solution. The supply curves are functions of production, transport, and processing costs, which are constants, but also of the prices of competing products which are endogenous variables. However, the demand curves remain the same because they are determined only by the level of income and population which are constant or exogenous in the model.

The specific model used for this study determines the consumption mix of products originating in the agricultural sector that maximizes total producer and consumer surplus given (*a*) the level of consumers' income, (*b*) the cost of production—both direct and opportunity costs, (*c*) the cost of transportation between markets, and (*d*) the net export and import prices.

The Formal Model

The objective function is

$$(1)\ \max f(w) = \sum_i \sum_j S_{ij}\lambda_{ij}(S_{ij}, I_j) + \sum_i \sum_j v_{ij}F_{ij} - \sum_n \sum_j d_{nj}M_{nj} - \sum_p \sum_j c_{pj}O_{pj} - \sum_i \sum_j u_{ij}G_{ij} - \sum_n \sum_j \sum_{\substack{k \\ j\neq k}} T_{njk}t_{njk} - \sum_r \sum_j \sum_{\substack{k \\ j\neq k}} T_{rjk}t_{rjk} - \sum_i \sum_j \sum_{\substack{k \\ j\neq k}} T_{ijk}t_{ijk},$$

where S_{ij} is the amount of ith product sold in the jth region ($i = 1, \ldots, I$, and $j = 1, \ldots, J$); λ_{ij} (S_{ij}, I_j) is the aggregate "utility" function for the ith product in the jth region, a function of the level of income, I_j—which is fixed or exogenous—and the amount consumed, S_{ij}; v_{ij} is the net price of ith product exported from the jth region;[1] F_{ij} is the amount of the ith product exported from the jth region; d_{nj} is the unit cost of converting the nth primary agricultural product in the jth region into consumer or final products ($n = 1, \ldots, N$); M_{nj} is the amount of the nth agricultural product converted into final product(s) in the jth region; O_{pj} is the level of the pth primary production activity, each usually producing more than one of the P primary products ($p = 1, \ldots, P$); c_{pj} is the unit cost of the pth primary production activity in the jth region; u_{ij} is the total import price of the ith product in the jth region; G_{ij} is the level of import of the ith product in the jth region; T_{njk} is the amount of the nth primary product transported from region j to region k and since intraregional transport is not considered, $j \neq k$; and t_{njk} is the cost of transporting one unit of the nth primary product from region j to region k. In other similar transport terms in equation (1), the subscript r refers to basic resources, $r = 1, \ldots, R$, and as noted above, i refers to final products or consumer goods.

In summary, equation (1) states that the objective of the programming model is to maximize the total net social payoff (producer's and consumer's surplus) of domestic sales plus the value of net exports of goods originating in agriculture, given consumer incomes in each region.

The constraints are specified in equations (2) through (8). Equation (2),

$$(2)\quad B_{jr} \geq \sum_p a_{pjr}O_{pj} + \sum_n a_{njr}M_{nj} + \sum_{\substack{k \\ j\neq k}} T_{rjk} - \sum_{\substack{j \\ j\neq k}} T_{rjk},$$

insures that the amount of the rth basic resource used by the primary production and processing activities plus the amount shipped into region j minus the amount shipped out

[1] The terms imports and exports refer to trade with other countries; the term shipment refers to interregional trade.

cannot exceed the fixed supply, B_{jr}. Equation (3),

$$(3)\ 0 \geq \sum_p \pm b_{pjn}O_{pj} + M_{nj} + \sum_{\substack{k \\ k\neq j}} T_{njk} - \sum_{\substack{j \\ j\neq k}} T_{njk},$$

states that the amount of the nth primary product processed in region j cannot exceed the net amount produced in the region by production activities,[2] P_{pj}, plus the amount shipped in minus the amount shipped out. Equation (4),

$$(4)\quad 0 \geq -b_{ijn}M_{nj} + S_{ij} + F_{ij} - G_{ij} + \sum_{\substack{k \\ k\neq j}} T_{ijk} - \sum_{\substack{j \\ j\neq k}} T_{ijk},$$

insures that the amount of the ith product sold in region j, S_{ij}, cannot exceed the amount processed in the region plus the amount shipped in minus the amount shipped out minus the amount exported plus the amount imported. Equation (5),

$$(5)\qquad E_i \geq \sum_j F_{ij},$$

insures that the amount of the ith product exported from all j regions must not exceed the upper bound or limit, E_i. Equation (6),

$$(6)\qquad H_i \geq \sum_j G_{ij},$$

restricts the amount of the ith product imported by all j regions to not exceed the upper bound or limit, H_i. These import and export bounds are set to make the programming solution trade levels consistent with government trade policy and/or world trade price conditions. Equation (7),

$$(7)\quad S_{ij}, M_{nj}, O_{pj}, F_{ij}, G_{ij}, T_{ijk}, T_{rjk}, T_{njk} \geq 0,$$

is the standard linear programming constraint which states that all programming activities and prices cannot be at negative levels.

In addition to these real constraints, there are IJ pseudoconstraints that are necessary to convert this nonlinear programming problem to a linear problem. The objective function is nonlinear because "utility" functions, λ_{ij}, are included in place of fixed prices for selling or consumption activities. This equation,

$$(8)\qquad K_{ij} \geq \sum_g k_{ijg} S_{ijg},$$

states that the weighted sum of the ith product sold in the jth region through all demand segments, g, cannot exceed K_{ij}, where K_{ij}/k_{ijg} is the maximum amount that can be sold through demand segment g. The upper bound, K_{ij}, would never be set above the amount for which total utility is a maximum. The value of g varies with the amount of precision desired in approximating the utility function. A fuller explanation of the construction of the pseudoconstraints is given in the appendix.

The empirical model includes twenty-two final products, five intermediate products, i.e., primary products that can be used to produce either other primary or final products, nineteen primary products, eight import commodities, four export commodities, and thirteen basic resources. (All final products are listed later in table 3. Information about other products and resources and other basic data are available from the authors on request.)

Because there were no data for regional consumption, only for prices, a rather involved procedure was used to estimate regional demand functions. The first step was to estimate demand functions of the form

$$(9)\qquad P_{ij} = f(S_{ij}, I_j),$$

where S_{ij} = per capita consumption of the ith commodity in the jth region, P_{ij} = price of the ith commodity in the jth region, and I_j = average per capita income in the jth region. It would have been desirable to include prices of other substitute commodities in this function. However, food prices tend to be highly collinear, which makes it difficult to derive individual price elasticities.

Lack of regional data on consumption presented a very serious problem in estimating regional demands. A first attempt was made by estimating demand functions for each commodity at the national level. These functions were used to estimate quantities consumed by each region on the basis of average regional per capita income and prices. The resulting consumption patterns were compared with the country's consumption patterns and regional agricultural production patterns. These did not turn out very well. A second round allocation of regional consumption patterns was made on the basis of local production patterns for crops and livestock. Thus, a typical per capita food ration per annum was derived for each region. These were examined in terms of average kilograms, calories, and protein consumed per person. When any of these items seemed improbable, national totals were reallocated so as to move

[2] Production activities can also use primary products produced by other production activities, e.g., livestock activities use feed produced by crop activities.

regional consumption rates into a plausible range.

After these analyses, some formal expression of regional demands was still needed. Therefore, regional demand functions were derived on the assumption that given the present patterns of consumption, the price and income elasticities were the same in all regions. This is not very satisfactory, of course, but it seemed to be the most practical course under the circumstances.

For programming purposes, as indicated by equation (8), the equilibrium demand (supply price equal to demand price) was approximated by using segmented demand functions. Moreover, because of the nature of the objective function, the marginal area under the demand curve was used (which is assumed to be equal to marginal utility), which is equal to price as a mathematical limit (see appendix). The supply-demand market equilibrium can be approximated as accurately as desired by segmenting the utility function into smaller and smaller intervals. In general, the programming routines used ten segments, with prices ranging from 20% higher to 20% lower than the base price.

Analysis with Two Levels of Aggregation

Because the model is so complex, no attempt was made to determine aggregation bias using general analytical methods. The method used is empirical. First, the model was solved using data for the eleven regions shown in figure 2. A second solution to the model was obtained after aggregating the eleven regions into three regions.[3]

This association of areas follows natural physical and climatic regions of the country, usually referred to as (1) above the river Tejo, (2) below the river Tejo, and (3) the Algarve. Macroregion 1 is hilly and mountainous with very intensive farming in narrow valleys and on terraces. Annual rainfall is highest in this area. On the other hand, macroregion 2 is a gently rolling area of both small and large farms. A major part of the farming is extensive. The major product is wheat, largely because of the meager rains which come mostly in the winter months. The Algarve is more like the north in topography and size of farm, but the pattern of rainfall is more like that of macroregion 2. Farming here is diversified with horticultural crops, fruits, and nuts being important as well as grain. Macroregion 3 in the aggregated model has the same boundaries as region 11 in the original model, because it is unique with respect to the surrounding areas and because a test of the idea that one area of a country can be analyzed in considerable detail while doing a more aggregate analysis for the rest of the country without giving serious bias to the results seemed desirable.

Basic resource constraints—land, labor, etc.—were obtained for the macroregions simply by adding the resource levels of the microregions. For aggregation, similar production activities were weighted by estimated production levels in the base period 1968. In a number of cases, unique crop rotations were specified for the microregions. Each rotation was defined for a specific number of years and produced a unique mix of crops—unlike any other in the related macroregion. In these cases, no aggregating was done and these activities have the same specifications in the micromodel.

Transportation activities were "aggregated" by establishing new transportation points near the centers of the macroregions and recalculating transfer costs between these points using the same rates per ton mile as for the eleven regions.

Commodity demand functions were derived for the macromodel by computing new functions for each commodity using price elasticities, base period prices weighted by base period consumption, and total base period consumption in the aggregated regions. Demand price elasticities were the same for each commodity across all regions in the eleven-region model. Demand functions "aggregated" in this way give an unbiased estimate of base period consumption and unbiased estimates of consumptions, if price changes within an aggregated region are proportional. (Proof of this statement is available from the authors upon request.) Unfortunately, there are no clear-cut rules for aggregating either regions or processing and demand functions in complex programming models of this type.

[3] The aggregation scheme is as follows:

microregions	macroregions
1, 2, 3, 4	1
5, 6, 7, 8, 9, 10	2
11	3

The terms micro and macro are used for convenience and do not imply any definitional significance.

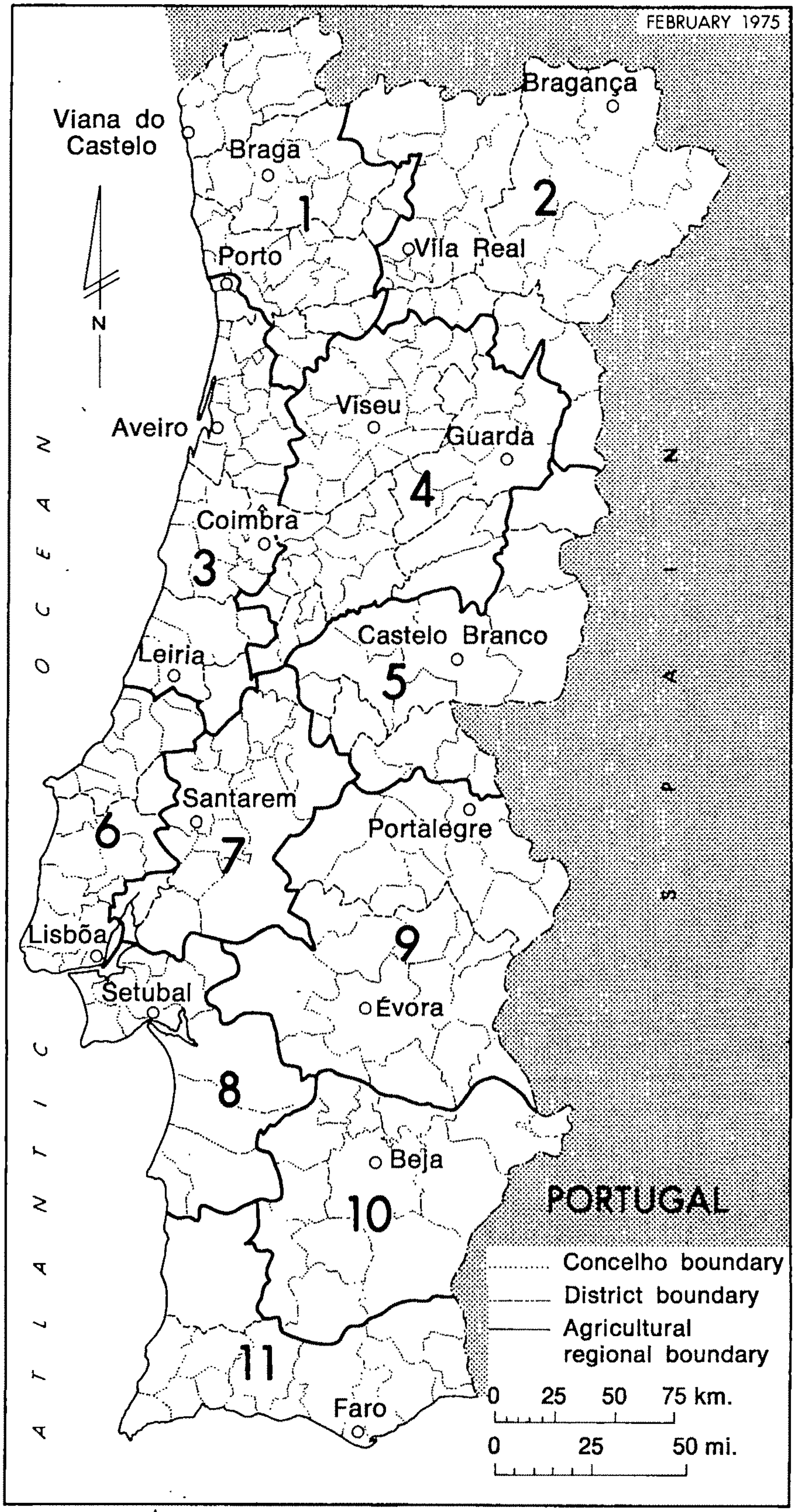

Figure 2. Programming regions

Aggregation Errors

There are a number of ways of approaching an evaluation of the results. We could compare item by item—production, consumption, prices, regional trade, imports and exports, and resource use—to see how they match up. But this is a tedious procedure involving great masses of data. (Anyone interested in the total set of regional and commodity data can obtain them from the authors on request.)

The procedure used in this study to compare micro- and macroresults employed a summary comparison statistic, U, developed by Theil (1966),[4] and a "bias" coefficient. To conserve space, the statistics are reported only for all commodities related to each macroregion as opposed to each commodity on a regional basis.

The U values for comparison of the macro- and microresults are presented in table 1. Roughly, the U coefficient of 0.06 for production in macroregion 1 means that there is an average difference of 6% between the production specifications for macroregion 1 and the sum of the production specifications of the large model for microregions 1, 2, 3, and 4. Thus, the correspondence between this set of specifications is quite good. On the other hand, the U value of 0.97 for regional imports, macroregion 1, indicates that the correspondence is very small. The general conclusion to be obtained from this table is that errors are greatest for the trade specifications, both internal and foreign, and except for processing in macroregion 1, all of the U values for production, food consumption, processing, and feed use are less than 0.2 or not excessively large. The results for macroregion 3 are not more consistent than for the other two regions except for trade specifications. Thus "a one region in depth—rest of the world analysis" does not seem very promising.

Another useful way to evaluate the results is by computing the bias (average signed error) in the aggregate specifications or by determining if the macroestimates are either larger or smaller than the microestimates on the average. If the weighted sum of the overestimates equals the weighted sum of the underestimates, the bias is zero. This statistic indicates that the bias is negative for foreign imports and exports in regions 1 and 2 (table 2). In other words, both imports and exports are underestimated in the macromodel. The lower import specifications are due to the fact that because of aggregation, domestic production potential is higher. Consequently, domestic costs are below import costs resulting in lower imports. On the export side, demand aggregation gives an upward bias to domestic demand; domestic prices are higher and, consequently, exports in total are less. For differences in prices and consumption for each model, see tables 3 and 4.

The reasons for the large biases in regional imports and exports are not easily discernible. The biases are both positive and negative (table 2). The comparisons are made only on a net trade basis for the micromodel, i.e., regional trade specified by the micromodel within the aggregated regions is omitted. Shipments between adjacent microregions of the macroregions theoretically cost more than actually reflected in the macromodel. On the

[4] This statistic is labeled as U and called an inequality coefficient by Theil. The formula for the U coefficient is

$$U = \sqrt{\frac{(O_2 - O_1)^2}{O_1^2}}$$

It is seen from this formula that if all the paired observations are equal, the value of U will be zero.

Table 1. Theil Statistics of the Correspondence between Micro- and Macromodel Results

Item	Macroregions 1	2	3	Total All Regions
Supply				
Production	0.06	0.17	0.13	0.09
Regional imports	0.97	0.90	0.45	0.41
Foreign imports	0.38	0.54	0.01	0.46
Disposition				
Food consumption	0.20	0.13	0.19	0.15
Processing	0.37	0.04	0	0.04
Feed	0.03	0.17	0.03	0.08
Regional exports	0.67	0.90	0.24	0.41
Foreign exports	0.31	0.28	—	0.32

Note: Statistics are computed by the formula given in footnote 4 for all commodities produced in each region.

Table 2. Percentage Bias in Macromodel Specifications

	Macroregions 1	2	3	Total: All Regions
Supply				
Production	5	13	1	8
Regional imports	68	−28	44	21
Foreign imports	−19	−39	1	−24
Disposition				
Food consumption	10	13	−5	11
Processing	41	−2	0	3
Feed	3	14	0	7
Regional exports	16	72	−19	21
Foreign exports	−31	−29	—	−24

Note: The formula for computing the bias is

$$\left[\sum_i \left(W_i \cdot \frac{O_{2i} - O_{1i}}{O_{1i}}\right)\right] \times 100,$$

where O_{2i} is the quantity of product i specified by macromodel, O_{1i} is the quantity of product i specified by micromodel, and $W_i = \frac{O_{1i}}{\sum_i O_{1i}}$; this formula can be simplified to

$$\frac{\sum_i (O_{2i} - O_{1i})}{\sum_i O_{1i}} \times 100.$$

other hand, shipments to the "extreme" microregions cost less. We can say no more at this point than that the regional trade specifications are different in the two models.

Positive biases in production and consumption are the result, at least in part, from a disassociation of specialized crop production activities from specialized inputs. For example, a region may have a better soil and climate for grape production. If this region is aggregated with a lower productivity region where production was not specified in the micromodel, the results of the macroproduction analyses may include production in all microregions making up a macroregion, resulting in greater production than that given by the micromodel. Because there is a positive bias in production specifications, regional commodity prices are usually less for the macromodel than for the micromodel (table 3). Obviously, this overproduction specification (lower cost) makes imports less competitive. Thus, imports fall in the macromodel. But it is not as easy to explain why exports decline.

In a number of instances, the production specifications for certain items are identical for the two models. For example, pork production in macroregion 1 is the same for both models, because the aggregated pork production activity was weighted by the swine inventory in each of the four microregions and production in each model was limited by swine inventory. Consequently, the results must be the same. This is true, too, for a number of other production specifications.

Table 3. Average Commodity Prices, Micro- and Macromodels (Escudos per Kilogram)

	Macroregions 1 Model		2 Model		3 Model	
Commodity	Micro[a]	Macro	Micro[a]	Macro	Micro[a]	Macro
Wheat	7.14	5.10	7.04	4.80	6.90	5.10
Rye	6.04	4.91	6.04	5.29	[c]	[c]
Corn	3.94	3.90	4.13	4.13	3.73	3.73
Barley	5.30	5.40	5.10	4.15	4.91	4.91
Rice	5.60	4.71	5.36	5.30	5.32	4.71
Beans	9.07	7.05	9.01	6.73	9.52	8.92
Chick peas	9.59	7.24	9.38	6.83	9.49	6.80
Potatoes	1.44	1.35	1.50	1.45	1.65	1.55
String beans	10.93	9.09	10.53	8.61	[c]	8.71
Oranges	7.16	[b]	6.83	7.30	6.85	[c]
Olive oil	18.96	[b]	18.73	19.22	18.94	[c]
Wine	5.34	5.53	5.36	5.57	5.48	5.74
Beef	32.30	31.60	32.96	31.27	32.20	30.80
Pork	30.64	30.37	31.08	31.41	30.72	30.72
Mutton	36.47	34.75	37.43	35.13	[b]	[b]
Cow milk	4.78	[b]	4.08	3.67	3.90	3.73
Cheese	61.03	55.87	61.82	56.36	61.97	56.34
Butter	46.60	36.13	46.76	35.97	46.00	36.00

[a] The prices listed in these columns are averages for the groupings given in footnote 3.
[b] Equilibrium price was not determined.
[c] No consumption was specified.

Table 4. Average per Capita Consumption, Micro- and Macromodels (Escudos per Kilogram)

	Macroregions					
	1 Model		2 Model		3 Model	
Commodity	Micro[a]	Macro	Micro[a]	Macro	Micro[a]	Macro
Wheat	63.8	72.3	85.7	97.7	113.3	125.4
Rye	17.0	21.3	13.8	16.2	—	—
Corn	36.1	36.2	23.3	23.2	25.3	25.6
Barley	0.3	0.3	0.4	0.4	0.5	0.5
Rice	12.4	14.8	41.1	49.0	29.1	32.6
Beans	1.6[d]	3.2	4.0[d]	6.5	10.8	11.2
Chick peas	0.8	1.0	1.6	3.2	1.7	2.0
Potatoes	119.5	122.3	88.3	89.3	81.4	83.2
String beans	8.0	9.4	1.9[d]	3.4	—	1.6
Oranges	12.9[d]	15.1	11.5[d]	17.2	15.4	—
Olive oil	4.9[d]	5.4	2.5[d]	4.3	5.3	—
Wine	76.4[d]	103.0	112.3	123.2	112.1	109.8
Beef[b]	7.5	7.7	9.9	10.5	3.7	3.9
Pork[b]	8.7	8.8	18.9	18.7	6.5	6.5
Mutton[b]	0.8[d]	1.1	5.2[d]	5.9	2.9	5.3
Cow milk	10.9[d]	27.5	38.7[d]	45.1	29.8	30.9
Cheese[c]	2.2[d]	2.5	2.9	3.1	2.4	2.5
Butter[c]	0.6[d]	0.7	0.7	1.0	0.3	0.4

[a] Per capita consumption levels listed in these columns are averages for the groupings given in footnote 3.
[b] Carcass weight.
[c] Product weight.
[d] No consumption was specified in at least one of the microregions in this group.

Differences in transportation costs apparently did not have a great impact on the results. In each of the models, intraregional transportation costs are lost or ignored. Calculated regional transportation cost is 432 million escudos in the micromodel but only 155 million in the macromodel. However, transportation costs do not make up a large part of the value of the output. Total value of domestic production at retail is about 16 billion escudos. Thus, accountable retail costs were reduced by 2% in the macromodel and likely had little influence on differences in results. This loss of information could be partly corrected by using intraregional transport activities based on a priori estimates of the average distance each commodity is shipped within each region. This practice could be useful for models with small as well as large regions, and the results would be more in line with national income accounting for the transportation sector.

Relative Costs

No complete records were made of the cost of constructing and solving the two models. If there had been, the numbers would not be strictly relevant for deciding whether to construct a large or small model because the microdata were assembled first and then aggregated. This is not the same as assembling sets of macro- and microdata from scratch. However, an idea of the total relative cost can be obtained from the tabulation in table 5.

In this case computer costs are not high enough to be a relevant consideration, even though costs did increase faster than size. It was found that for larger similar models, computer costs increased very rapidly somewhere between 1,000 and 1,400 rows by about six times. Thus, relative computer costs do become important for large models, given the current state of the art. Data assembly costs are another matter. It is probably fair to say

Table 5. Comparison of Size and Cost of Micro- and Macromodels

	Micromodel	Macromodel
Number of regions	11	3
Matrix: Rows	1,019	299
Columns	4,882	990
Nonzero elements	31,300	7,500
Systems seconds required to solve problem (CDC-6600)	750	150
Approximate cost	$ 250	$ 50

that assembly costs would increase in proportion to the size of the matrix.

Conclusions

It seems apparent from the results that simple aggregation procedures as used in the experiment summarized here can produce significant aggregation errors. Thus, if such models are used for development planning, serious mistakes could result.

Two sources of significant errors have been noted. First, aggregation can prevent regional specialization consistent with regional comparative advantage. Second, production activities requiring unique resources, i.e., water, soil, climate, labor, etc., may appear in the programming solutions at infeasible levels. Both factors are at work in the model as aggregated and the specialized activity error seems to be overriding because production is higher for most commodities in the macromodel. It is also possible that the absence of transportation charges reduces cost sufficiently to permit a larger output before marginal costs equal marginal returns. But because transportation costs are a relatively small fraction of the retail price, it is unlikely that the absence of transportation costs explains the overproduction. This point could be examined by doing sensitivity analysis on transportation costs. Even though transportation costs are not so improtant in a small country like Portugal, in large countries where only a few regions can be handled in the analysis, they would be important. But as noted above, a better procedure than omitting intraregional transport charges is to make a priori estimates of average transport cost for each commodity within each region.

A simple way out of the resource specific and regional comparative advantage problems in models with large regions is to group or stratify activities by intraregional location and unique resource needs. Thus, it is possible to "tie" specific activities to particular locations or resources in macroregions. The programming matrix would have the same number of resource constraints and the same number of production activities, but the number of processing, demand, and transport activities would be drastically reduced. For example, if a ten-region model with five resources, ten products, twenty production activities, and ten demand segments is reduced to five regions, the matrix will be less than one-quarter the size of the ten-region matrix.[5]

Finally, these conclusions are just as valid for regional programming models of industrial and other sectors as for agriculture. The principles are the same.

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[5] The formula is

$$M = [[p + (k + 1)m]n + mn(n - 1)] \times [(r + 2m)n],$$

where p is the number of production activities, k is the number of demand segments, m is the number of products, and n is the number of resources.

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Appendix

Derivation of Utility Function from Demand Function and Constructing Matrix for Linear Approximation for Programming

Given demand functions of the form,

$$P_{ij} = a_{ij} - b_{ij}S_{ij}, \tag{A.1}$$

where P_{ij} is the price of product i in region j, S_{ij} is the amount of product i consumed in region i, a_{ij} and b_{ij} are constants, and assuming that $P_{ij} = \frac{dU_{ij}}{dS_{ij}}$, where $\frac{dU_{ij}}{dS_{ij}}$ is the marginal utility of consuming product i in region j, which is theoretically true if marginal utility of income is constant and equal to $1, total utility, U_{ij}, is obtained by

$$U_{ij} = \int_S (a_{ij} - b_{ij}S_{ij})\, dS_{ij}, \tag{A.2}$$

and

$$U_{ij} = a_{ij}S_{ij} - \frac{b_{ij}}{2}S^2_{ij}. \tag{A.3}$$

For programming purposes, equation (A.3) was approximated by segmenting the function for 10 (n = 1, . . . , 10) discrete levels of S_{ij}; an additional convex constraint was also needed.

To illustrate, assume that

$$U_{ij} = 100\, S_{ij} - 0.25\, S^2_{ij}. \tag{A.4}$$

Evaluating equation (A.4) for (N = 3), S_{ij} (1) = 20, S_{ij} (2) = 30, S_{ij} (3) = 40, U_{ij} (1) = 1,900, U_{ij} (2) = 2.775, and U_{ij} (3) = 3,600. Since $\lambda_{ij} = U_{ij}/S_{ij}$, λ_{ij} (1) = 95, λ_{ij} (2) = 92.5, and λ_{ij} (3) = 90.

The partial programming matrix is

objective function		=	90	92.5	95
supply row for S_{ij}	0	$\geqslant$	1	1	1
convex constraint	40	$\geqslant$	1	4/3	2.

The coefficients of the convex constraint row are the ratios from equation (8), $\frac{K_{ij}}{S_{ijn}} = k_{ijn}$. In the example, $\frac{K_{ij}}{S_{ij}(1)} = \frac{40}{20} = 2, \frac{K_{ij}}{S_{ij}(2)} = \frac{40}{30} = \frac{4}{3}$ and, $\frac{K_{ij}}{S_{ij}(3)} = \frac{40}{40} = 1.$ Then, by proper row and column divisions, i.e., by dividing the convex constraint row by forty and then each column by the resulting coefficient in the convex constraint row, the matrix becomes

objective function		=	3,600	2,775	1,900
supply row for S_{ij}	0	$\geqslant$	40	30	20
convex constraint	1	$\geqslant$	1	1	1

This form was used for programming because it is easily generated by the computer.

Finally, because the U_{ij}s have a common constraint,

$\Delta U_{ij}(1) = U_{ij}(1) - 0,$ for $S_{ij}(1) - 0,$
$\Delta U_{ij}(2) = U_{ij}(2) - U_{ij}(1),$ for $S_{ij}(2) - S_{ij}(1),$ and
$\Delta U_{ij}(3) = U_{ij}(3) - U_{ij}(2),$ for $S_{ij}(3) - S_{ij}(2).$

Hence, as $\Delta Q_{ij} \rightarrow d(S_{ij})$, $\Delta U_{ij} \rightarrow P_{ij}$.

Ownership of Farm Trucks for Hauling Grain: An Application of Multivariate Logit Analysis

Surendra N. Kulshreshtha

In calculating the cost of hauling grain with respect to a change in hauling distance, the nature of the truck maintained by a farmer is usually assumed to remain the same. Logit analysis is applied to estimate the relationship between the size and age of grain trucks and the distance to an elevator. The estimated probability of a farmer maintaining a larger and/or a newer truck increases as hauling distance becomes longer.

Key words: transportation, trucking costs, grain marketing, logit analysis.

Past studies dealing with the impact on farmers of a change in the branch railway line system have assumed that increased distances between farms and grain delivery points, such as country elevators, would not necessitate a change in the nature of the trucks used by farmers for hauling grain. For example, studies by P. S. Ross & Partners, Ash, Kaldenberg, and Tyrchniewicz and Tosterud, attempting to develop a rationalized transportation system, appear to have held the nature of the truck owned as a constant in calculating the producers' costs of hauling grain over a varying range of distances.[1] This implies that the truck used by a farmer for hauling grain would be unaffected by an increased hauling distance. Although one may argue that this is true under a small change in hauling distance, its validity under a drastic change in distance is open to question.[2] The primary objective of this paper is to examine the effect of hauling distances on two major characteristics of farm trucks used for hauling grain: size and age. The relationship between distance and the nature of the truck is examined by applying multivariate logit analysis to data obtained from a survey conducted in the province of Saskatchewan.[3]

Conceptual Considerations

A grain producer's decision to maintain a certain type of truck is made in light of a number of considerations.[4] In addition to the personal preferences of a farmer, the primary consideration is the nature of the job to be performed. The nature of the job, in the context of grain hauling, can be conceived of in two dimensions: volume of various grains to be hauled and the distance between various collection points and the farm unit.[5] One hypothesis is that a farmer maintains a truck that minimizes the cost to the farm business and at the same time provides him with a minimum acceptable level of dependability in various hauling operations. If this is true, farmers with smaller volumes hauling over shorter distances would be able to maintain small, relatively older

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[1] The study by Tyrchniewicz and Tosterud used the producer cost of hauling grain by farm trucks as developed by Trychniewicz, Butler, and Tangri. This cost was estimated using a cost function. The study, however, did not explicitly mention that, with increasing hauling distances, truck size and age characteristics were changed.

[2] The term "drastic" has subjective interpretations and can only be defined in relative terms. For farmers hauling two miles, a change to fifteen miles may appear drastic, whereas to those who are hauling ten miles, a drastic change might be the one which involves hauls over thirty miles.

[3] The survey was carried out during the fall of 1972 for the Government of Saskatchewan, Grain Handling and Transportation Systems Rationalization Office. (For further details, see Kulshreshtha.)

[4] The term "type" refers to the two characteristics, size and age of truck.

[5] A collection point can be a country elevator, terminal elevator, feedlot, seed plant, or a neighbor's farm.

trucks than those maintained by farmers with larger volumes hauling over longer distances.

When hauling distance changes, a farmer with a given volume to deliver has three options open to him: (*a*) maintain the same truck as used prior to the change in distance, (*b*) maintain the truck already owned for general farm operations but obtain the services of a custom trucker, or (*c*) purchase a new and larger truck.[6] Although individual preferences play a significant role in deciding which option a farmer chooses, theoretically he would opt for a dependable alternative which minimizes the cost to the farm.[7] However, as either the distance to the elevator or size of the grain delivery job increases, a farmer would tend to maintain a larger truck. Such a choice would be more economical since, as distance increases, the labor costs for a small truck increase.[8] On the other hand, the effect of the size of the farm or of distance on the age of the truck can be hypothesized to be negative, that is, larger farms and those located farther from the elevator would tend to maintain newer model trucks. As either the farm size or hauling distance increases, the productive life (in years) of the truck is reduced, and with longer hauling distance an older truck might be considered less dependable due to a larger risk of breakdown.

The type of grain truck maintained by a farm may be considered a dichotomous characteristic. A particular type of truck either is maintained on a farm or it is not. The analyst's objective is to find out the factor(s) which determines such a decision on the part of the farmer. One approach is to formulate a regression equation with a binary dependent variable. However, in such an equation, estimation of parameters by conventional regression techniques is inappropriate due to two problems. First, the predicted values of the dependent variables might not be confined within a zero-one interval and second, the disturbance terms are heteroskedastic (see Goldberger, p. 249).

[6] One might argue that when buying a new truck, a farmer generally opts for a larger truck. Although such a decision may be justified on personal grounds, it may not be a rational choice based on economic logic.

[7] During the course of the personal interviews as reported by Kulshreshtha, many small farmers indicated that a decision to own a truck rather than hiring a custom trucker was guided by the lack of dependability of such truckers.

[8] This is because the total labor input is directly proportional to the number of trips a farmer makes to a delivery point. Labor input per trip is also positively, although in curvilinear fashion, related to the distance between a farm and a delivery point.

An alternative to this method of estimation is provided by transforming the equation into a logit analysis. According to Theil (p. 632), the logit function is written as

$$(1)\qquad P(R)_\alpha = \frac{1}{1 + e^{(-\beta_0 - \Sigma_i \beta_i \log X_{i\alpha})}}$$

$$\alpha = 1, 2, \ldots, n.$$

Equation (1) after manipulation can be written as

$$(2)\quad \ln\left[\frac{P(R)_\alpha}{1 - P(R)_\alpha}\right] = \beta_o + \sum_{i=1}^{k} \beta_i \ln X_{i\alpha}.$$

The logit function can be fitted to a set of cross-section data, which is subdivided into a number of groups, each with a probability, $P(R)_\alpha$, and a level of independent variables. Let $G_\alpha = \left[\frac{P(R)_\alpha}{1 - P(R)_\alpha}\right]$; then equation (2) can be rewritten as

$$(3)\ \ln G_\alpha = \beta_o + \beta_1 \ln X_{1\alpha} + \ldots + \beta_k \ln X_{k\alpha} + \nu_\alpha,$$

where $\beta_o, \beta_1, \ldots, \beta_k$, are the parameters to be estimated, and ν_α is a stochastic error term.

Data and Methodology

Data used in this study were collected under the auspices of a survey of four selected areas of Saskatchewan. The total number of trucks in the sample was 430. The sample included a number of farms on which 2 or more trucks were used for hauling grain. However, it excluded those which did not have a truck on the farm or did not use one for grain hauling.[9] Data were recorded on various truck characteristics as well as on other economic and physical variables related to grain hauling. The trucks were classified into various cells based on two characteristics: size of the grain hauling job, which was measured in terms of average volume of grain delivered by a truck, and distance to elevator in miles. The final stratification yielded thirty-six cells. When the sample of 430 trucks was stratified by these characteristics, some of these cells had very few or no trucks. Such cells were subsequently merged with neighboring cells. The final sample included twenty-six groups of

[9] The number of farms which did not own a truck in 1970 was only 8% of all commercial farms in the province. Those farmers who owned a truck but did not use it for hauling grain were subsequently included in the analysis of custom truckers' use.

Table 1. Distribution of Farm Trucks in the Sample by Size of Farm and Distance

Size of Farm (in terms of volume of grain delivered in 1,000 bushels)		Distance in Miles ≤6	6–11	11–21	21–31	31–41	41
<4	(1)[a]	1	2	3	4	5	6
	(2)	34	26	19	16	11	16
4–8	(1)	7	8	9	10	11	12
	(2)	50	26	9	3	3	4
8–12	(1)	13	14	15		16	
	(2)	26	35	8		3	
12–16	(1)	17	18		19		
	(2)	30	19		8		
16–20	(1)	20	21		22		
	(2)	16	15		5		
>20	(1)	23	24	25		26	
	(2)	18	21	4		5	

[a] The two figures in each cell are cell number and number of trucks.

distance-size of farm situations. Thus, n in equation (3) is twenty-six. Distribution of the number of trucks in the various cells is shown in table 1.

Six logit variables were defined—three dealing with size and the other three with age. Truck sizes were defined as (*a*) smaller than or equal to 1½ tons with a grain box capacity of less than 150 bushels, (*b*) larger than 1½ tons but smaller than 2½ tons with a grain box capacity between 151 and 225 bushels, and (*c*) larger than or equal to 2½ tons with a grain box capacity of more than 226 bushels. Similarly, the age categories were: (*a*) new models belonging to and including 1965 to 1973, (*b*) medium-old models prior to 1965 but later than 1954, and (*c*) old models prior to and including 1954. The values for the variables appearing on the right-hand side of equation (3) were averages for the trucks appearing in a given αth cell.

It was hypothesized that the decision to maintain a certain size grain truck on a farm would be determined by three factors: X_1 = size of farm in terms of volume of grain delivered annually, X_2 = one-way distance to elevator in miles, and X_3 = dependence on grain as a source of income defined in terms of percentage of total gross farm income derived from grain. Similarly, the decision to maintain a certain age grain truck was hypothesized to be determined by X_1 and X_2, as defined above, and by X_4 = age of the farmer.

Multivariate logit functions, as expressed by equation (3), were estimated for the six classes of trucks by applying weighted least squares. Choice of this technique[10] was guided primarily by the heteroskedastic nature of the error term.[11] Other assumptions regarding the error term included randomness, independence between error terms of one cell and the other cells, and a lack of correlation between the error term and the variables appearing on the right-hand side of the equation.

Empirical Results

Estimated Logit Functions

Estimated logit functions for the ownership of farm trucks of various sizes are shown in table

[10] In principle, an alternative method of estimation for logit functions is using a maximum likelihood criterion.

[11] The variance of the error term for the αth cell is

$$\text{var}(v_\alpha) = \frac{1}{n_\alpha^2}[\sigma^2 + \ldots + \sigma^2] = \frac{n_\alpha \sigma^2}{n_\alpha^2} = \frac{\sigma^2}{n_\alpha},$$

where n_α is the number of observations in αth cell. Unequal numbers of observations in the various cells produce heteroskedasticity. If the Y and X values are multiplied by the square roots of the number in the respective cells, the resulting error terms have a common variance, σ^2 (see Theil, pp. 633–35).

Table 2. Estimated Weighted Least-Squares Coefficients of Logit Functions for Trucks Classified by Size of the Truck

Dependent Variable ln G_α for:	Intercept	Estimated Coefficient and t-value[a] for: X_1 Volume of Grain Delivered[b]	X_2 One-Way Distance to Elevator[b]	X_3 Dependence on Grain[b]
Small trucks	5.004	−1.594	−0.925	0.785
		(4.88)	(2.39)	(0.32)
Medium trucks	0.655	0.318	−0.535	−1.007
		(0.74)	(1.04)	(0.31)
Large trucks	−6.304	0.919	0.998	0.895
		(2.68)	(2.45)	(0.35)

[a] Critical values of t are 2.069 and 2.807 for 5% and 1% level, respectively.
[b] All variables are in natural logarithms.

2. According to the estimated coefficient, both the size of the farm and the distance between the farm and a delivery point were negatively related to the logit value for small trucks. As distance to elevator increases, the probability of a farmer deciding to maintain a small truck for grain hauling decreases. Similarly, as either volume of grain delivered or distance to elevator increases, the probability of a farmer maintaining a large truck for grain hauling also increases. The coefficient with respect to dependence on grain had small t-ratios in all three equations. This was probably caused by a relative homogeneity of farms with respect to their dependence on grain farming.

Empirical logit functions for the ownership of trucks of various ages are shown in table 3. The logit functions for age were inversely related to the size of the farm and the distance to the elevator. The age of the farmer was negatively related to the decision to operate a new truck for grain hauling, but the coefficient for age of the farmer had small t-ratios for the other two truck age categories.

Evaluation of Logit Functions

The empirical logit functions were tested for representing the actual situation which existed with respect to the ownership of a grain truck under varying distances to the elevator and sizes of the farms. The estimated probabilities were compared with those based on the actual distribution of trucks. A Chi-square test, as presented by equation (4), was used to test whether the actual probability distribution to own a certain type of truck was similar to that estimated using a logit function:

$$(4) \qquad \chi^2 = \sum_{\alpha=1}^{26} \left[\frac{(E_\alpha - A_\alpha)^2}{E_\alpha}\right],$$

where E_α and A_α are the estimated and actual number of grain trucks of a specific type. All the estimated χ^2 values were found to be

Table 3. Estimated Weighted Least-Squares Coefficients of Logit Functions for Trucks Classified by Age of the Truck

Dependent Variable ln G_α for:	Intercept	Estimated Coefficients and t-value[a] for: X_1 Volume of Grain Delivered[b]	X_2 One-Way Distance to Elevator[b]	X_4 Age of Farmer[b]
New trucks	−2.510	0.888	1.105	−1.434
		(3.75)	(4.66)	(2.36)
Medium-old trucks	−5.190	0.425	0.069	1.816
		(1.03)	(0.29)	(0.59)
Old trucks	3.877	−0.791	−0.911	−0.136
		(2.64)	(3.17)	(0.16)

[a] Critical values of t are 2.069 and 2.807 for 5% and 1% level, respectively.
[b] All variables are in natural logarithms.

smaller than the critical value, suggesting that the actual distribution of trucks and that based on logit functions are statistically equivalent.[12]

The logit functions were used for predicting the ownership of trucks for grain hauling purposes under the assumption of changing distances between a farm and a country elevator. Probabilities for ownership of variously sized trucks were estimated for two farm type situations—for a small farm delivering about 3,000 bushels of grain annually and for a large farm delivering 15,000 bushels annually. These estimated probabilities are shown in figure 1. As the distance increases, the probabilities for the ownership of small grain trucks decline sharply. This decline was more prominent in the case of a small farm.

Estimated probabilities for older trucks as distance between a farm and an elevator changes are shown in figure 2. As the distance between a farm and an elevator increased, the probability that a farmer would maintain an older truck declined.

Hauling Distance and the Emergence of Custom Trucking

During the course of the survey, in the area of longer distances to haul, a slightly higher incidence of custom trucking of grain was also observed. Therefore, the analysis of the pattern of ownership of trucks would not be complete without identifying the reasons for the use of a custom trucker. Further investigation of seventy-nine farmers who had used the services of a custom trucker during 1971–72 was carried out. The following relationship was estimated:[13]

$$(5)\quad \hat{Y} = \underset{}{27.136} - \underset{(3.786)}{11.367\, X_1} + \underset{(0.435)}{0.149\, X_2} - \underset{(1.762)}{0.0007\, X_3} + \underset{(7.181)}{1.301\, X_4} + \underset{(1.707)}{0.350\, X_5}$$

$$R^2 = 0.71,\ S_y = 20.89,$$

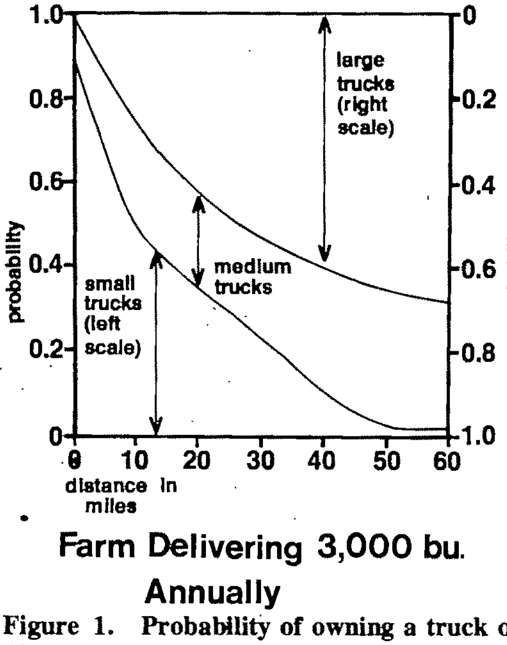
where Y = proportion of annual volume of grain delivered through a custom truck (in percent), X_1 = size of truck, measured in tons,[14] X_2 = age of the truck in years (1972 = 1, 1971 = 2, . . .), X_3 = annual volume of grain delivered (in bushels), X_4 = one-way distance to elevator (in miles), and X_5 = age of the farmer (in years).

On the basis of these results, it can be inferred that a heavier usage of a custom trucker is made by those farmers who have a small truck, a small volume of grain to deliver annually, and a longer distance to haul. The effects of the age of the truck and the age of the

[12] The estimated χ^2 values, for example, were 16.84 for small trucks, 14.28 for large trucks, and 23.76 for old trucks. The critical value of χ^2 for 25° of freedom and 5% level of significance was 37.652.

[13] Figures below the regression coefficients are the respective t-values.

[14] This refers to the truck maintained on a farm regardless of whether it is used for hauling grain.



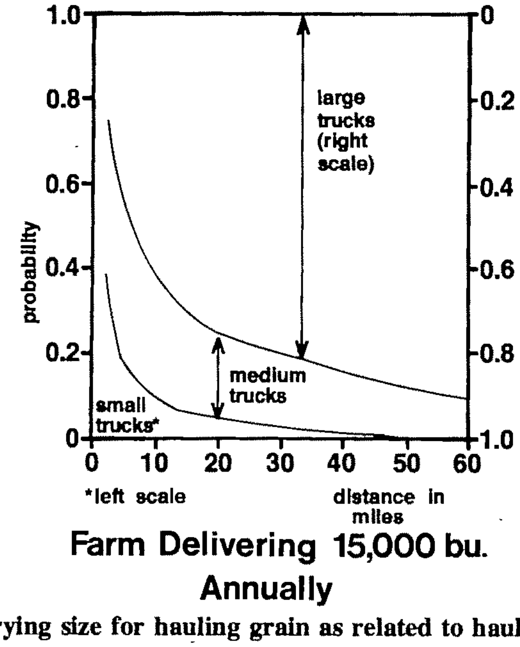


Figure 1. Probability of owning a truck of varying size for hauling grain as related to hauling distance

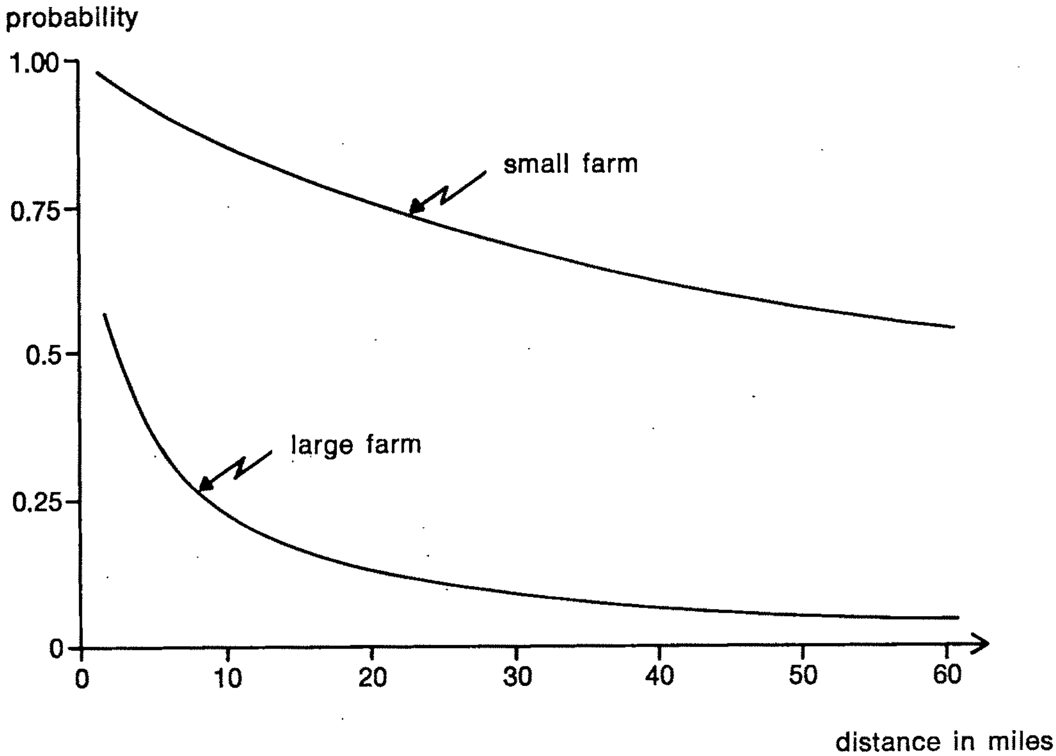


Figure 2. Probability of owning an older truck (18 years or older) for hauling grain, small and large farm, as related to hauling distance

farmer variables had small *t*-values. This suggests that as distance to haul increases, a few farmers (still owning a smaller truck) frequently use the services of a custom trucker.

Implications for Policy

As distance between a farm and a delivery point increases, the probability of a farmer's maintaining a larger and newer truck also increases. In addition, those farmers who, with longer distances to haul, maintain a small truck depend more heavily on the services of a custom trucker than either those with shorter hauling distances or those with larger trucks.

These results have a number of implications for the rationalization of a grain transportation system on the prairies. First, the marginal cost of hauling grain with respect to changing distance should take into account the probable change in the characteristics (size and age) of the truck as related to the increased distance. Failure to consider this change would be to underestimate the producers' cost and thereby reduce the total cost of hauling under alternate configurations of the rationalized grain transportation system.

Second, the analysis suggests that the probability of a change in truck characteristic(s) is larger for a small farm than for a larger farm. Many larger units already maintain a large truck and therefore would be less affected by increased hauling distances. The relative change in the cost of hauling grain apparently would be larger for small farms than for larger farms. Therefore, alternate rationalized grain transportation systems may have a distributional effect on various producers with a subsequent effect on the number of farmers on the prairies.

Third, the necessity for a change in the nature of a truck, particularly on small farms, would affect the cost to the farm business in addition to the cost of hauling grain. The cost of performing other hauling activities such as hauling livestock and other products, moving grain from combine to farm storage, and doing miscellaneous farm chores would also increase. This would imply that a change in the hauling distance for grain would result in larger increases of cost for smaller farms.

Perhaps a case can be made for the development of a compensation policy for grain producers who stand to be adversely affected by a change in the transportation system.[15]

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[15] In order to be fair and equitable, a compensation policy should include not only producers but all other parties who stand to be adversely affected by such a change. The topic of compensation is too broad and complex to deal with in this paper.

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A Cross-Spectral Analysis of Beef Prices

Hiram C. Barksdale, Jimmy E. Hilliard, and Mikael C. Ahlund

Changes in retail beef prices lag price changes at other market levels. At the slaughter level, quantity lags prices by approximately nine months over the higher frequencies (short run), but price and quantity are out of phase over the lower frequencies (long run). Independent causality tests support the spectral interpretations.

Key words: spectral analysis, beef prices, price-quantity relationships, causality tests.

In an article in this *Journal,* Franzmann and Walker developed models of feeder, slaughter, and wholesale beef prices. The procedure involved postulating models with trend, cyclical, and seasonal components and used harmonic analysis to estimate the lead-lag relationships among beef prices at three market levels. The authors concluded that wholesale beef prices lead slaughter prices and slaughter prices lead feeder prices, both cyclically and seasonally. However, the authors acknowledged the poor statistical fit of some of the models (Franzmann and Walker, p. 510).

When cross-spectral methods are used to study beef prices at different market levels, the timing relationships that emerge are not consistent with those reported by Franzmann and Walker. While it is possible that the discrepancies are partially due to the differences in the price series, they more likely result from differences in the analytical techniques employed in the two studies.

The main objective of this paper is to report the lead-lag relations among beef prices at four different market levels—feeder, live animal, wholesale, and retail—derived by cross-spectral analysis. In addition, the timing relationship between price and quantity of beef cattle at the live animal level is analyzed. "Causality" tests are used to confirm the direction of influence revealed by the spectral analysis. Finally, the seasonality of beef prices at different levels of the production-distribution process is discussed.

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Data and Methodology

The primary data used in this analysis are monthly estimates of beef prices at the feeder, live animal, wholesale, and retail market levels. In addition, monthly estimates of the total liveweight of slaughtered commercial cattle were studied. Each of the series included 288 observations beginning January 1949 and ending December 1972.

The feeder price series is the weighted average cost of feeder steers at selected stockyards. The live animal data represent the average price of choice grade steers at major stockyards and the average of quotations to California feeders and ranchers. The wholesale series is an average of price quotations for choice grade carcass beef at Chicago and three West Coast markets—Los Angeles, San Francisco, and the Seattle area. The retail data are average prices of all saleable cuts obtained from choice carcass beef. The slaughter series is the estimated total liveweight of all cattle slaughtered commercially. (The feeder, live animal, and wholesale price series and the quantity estimates of commercial cattle slaughtered are published in *Livestock and Meat Statistics.* The retail price data were supplied by Economic Research Service, USDA.)

Cross-spectral analysis is particularly appropriate in exploratory studies of this nature since the technique does not require rigid model prespecification. Although the assumption that the data sequences are jointly covariance-stationary is necessary, filtering procedures are available that may be used

when needed to screen out or reduce trend components and create series that can be treated as stationary. Cross-spectral analysis depends little on model assumptions; instead the power of the technique, in part, is that it suggests models. Moreover, some cross-spectral statistics, especially phase, are remarkably robust to mild violation of the stationarity assumption (Granger and Hatanaka, p. 168).

Our interpretation of spectral statistics is consistent with standard interpretations found in the literature. Nevertheless, the interpretation of the phase statistic is reviewed since misunderstanding of its implications seems to exist. First consider the τ (tau) statistic, defined by

$$\tau = \text{phase angle/angular frequency} = \phi(\omega)/\omega, \qquad \omega \neq 0,$$

where $\omega = 2\pi f$ is the angular frequency and $\phi(\omega)$ is the phase angle at frequency $f = \omega/2\pi$. The significant property of τ is that an advance of the output series by τ time units will maximize the covariance between the in-phase components of the two series at frequency f. Similarly, τ is that time displacement which minimizes the expected error sum of squares at frequency f. In an intuitive sense, the appropriate time shift τ best "aligns" the processes at a given frequency. The statistic τ is especially useful when the phase diagram approximates linearity over a subset of frequencies, say Ω, for in this case τ does not depend on frequency (assuming a zero phase intercept) and so a single time shift will align the series at all frequencies in the Ω subset. In the case of a zero intercept, τ is equivalent to the slope of the phase diagram, since $\tau = \phi(\omega)/\omega = a\omega/\omega = a$, where a is the slope of the $\phi(\omega)$ versus ω diagram. So τ, in the case of straight line segments, presents a natural way to quantify the concept of leads and lags in the time-domain invariant of frequency.

Empirical Results

Visual inspection of the original series indicates that none were stationary. Therefore, to reduce the trend component, least-squares polynomials were applied to the original series. Also, a first-difference filter was used to eliminate the trend from the original observations and the logarithmic transformations of each series. The residual series produced by these high pass filters were then tested for stationarity using runs tests. These indicated that the third-order polynomial and the first-difference filter yielded residual series with means and variance patterns that were constant. The spectral estimates were calculated using a remodeled version of the program outlined by Jenkins and Watts. Parzen weights were used and the spectral statistics were computed using covariances with a maximum lag of 36.

Although complete cross-spectral statistics were calculated for all combinations or pairs of residual prices, only the analysis of the third-order polynomial residuals will be presented here. (The spectral estimates derived from the residuals of the first-difference filter, for both the original series and the logarithmic transformations, are essentially the same as those reported in this paper.) Estimates of the autospectra were computed for prices at each of four market levels. Cross-spectral statistics were also computed for prices at each pair of market levels as well as for prices versus quantity at the slaughter level. Rather than separately analyzing each of these statistics, attention is focused on the topics discussed earlier, selecting the most appropriate spectral results to illuminate the key ideas.

Lag Structure Of Beef Prices

The interaction of supply and demand operates at the feeder, live animal, wholesale, and retail market levels to set beef prices, but interdependence exists among the different market levels. Measurement of the lead-lag relations among different market levels should provide insight into the dynamic structure of the market mechanism for beef prices. Alternative possibilities include (*a*) prices determined at the retail level with prices at other levels derived by "market-minus" calculations with or without some time displacement between the different markets, (*b*) prices established primarily at the feeder level and prices at other levels fixed by "cost-plus" methods with or without some time lag, or (*c*) prices set at an intermediate level and other prices are established by "market-minus" or "cost-plus" methods with lead-lag relations among markets.

The phase estimates give the timing relations among beef prices at different market levels. The tau statistic suggests that retail prices lag wholesale prices by approximately

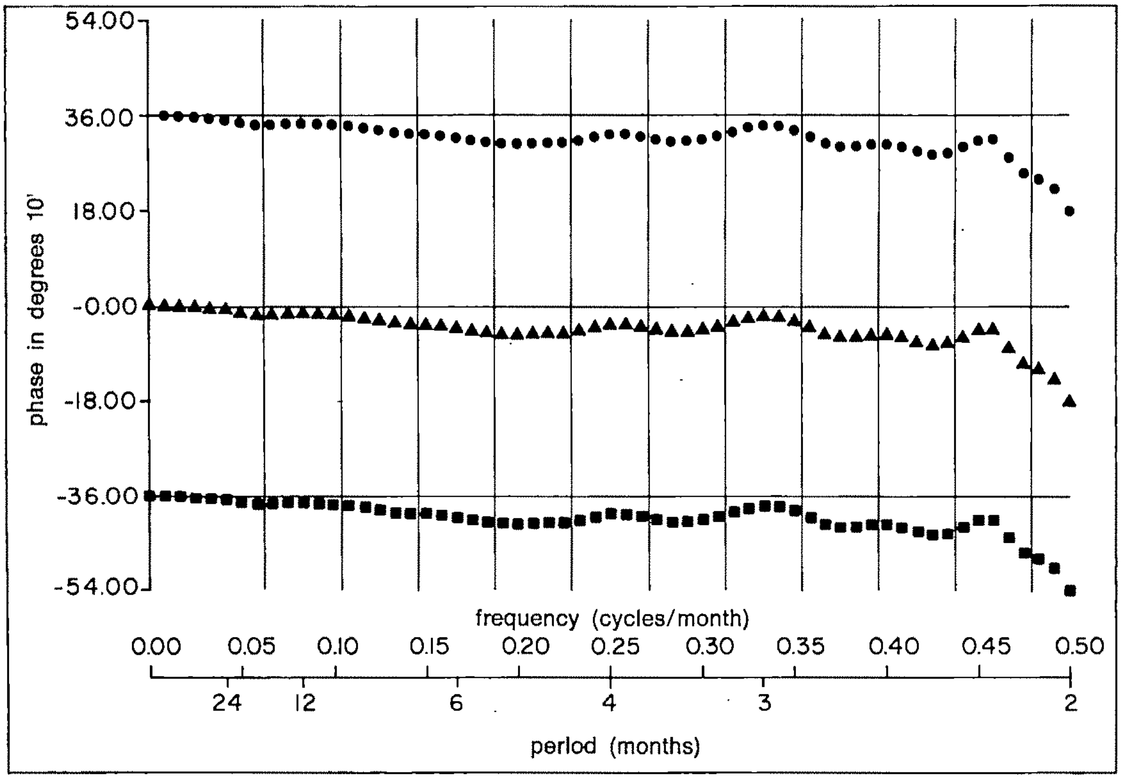

Figure 1. Phase diagram: wholesale-retail beef prices, 1949–72. The phase estimates are plotted with rotations of 360° to facilitate identification of straight line segments.

three weeks (fig. 1), while prices at the feeder, live animal, and wholesale levels move together and the phase statistics are virtually coincidental. Although the estimated three-week lag is a fraction of the one-month sampling interval, it is a valid interpretation of the lag structure (Labys and Granger, p. 51). The obvious conclusion, therefore, is that beef prices are not established at the retail level.

The spectral estimates for feeder, live animal, and wholesale prices cannot be used to determine more precisely the market-making mechanism at the first three levels since prices in these markets are in virtually perfect phase agreement. These results do not necessarily imply that the production-distribution system for beef is nonresponsive to consumer demand in terms of prices. However, they do show that the first indication of price change does not occur at the retail level. In this respect, the conclusions here differ from those developed via harmonic analysis by Franzmann and Walker. They concluded that wholesale prices lead slaughter prices and slaughter prices lead feeder prices.

Thus, the analytic approach chosen and its corresponding interpretation is of critical importance. There appears to be significant mathematical rationale for choosing cross-spectral analysis over harmonic analysis in the present application, however. Harmonic analysis of leads and lags corresponds closely to the use of the phase diagram (in cross-spectral analysis) if emphasis is placed on interpretation at a single frequency. In this case, a fundamental ambiguity is involved. Specifically, a relationship between components may correspond to an angular lead of, say 90°, or a lag of 270°. For any point on the phase diagram or term in a harmonic analysis, multiples of 360° may be added or subtracted because of the properties of the trigonometric functions involved; therefore, it is not mathematically possible to distinguish between a lead and a lag. However, the ambiguity may often be resolved in spectral analysis by use of the tau statistic and by focusing on straight line segments of the phase diagram.

Price-Quantity Relationships

Fluctuations in price will affect the quantity supplied. Accordingly, a rise in price should

trigger an increase in quantity supplied —within certain constraints imposed by the nature of the production-distribution process. This increased quantity, *ceteris paribus,* leads to lower prices. In dynamic analysis, this shift in causality is frequently analyzed using cobweb type equations. An alternative type of analysis can be developed from cross-spectral statistics. The empirically derived phase diagram for price versus supply of cattle at the slaughter level is given in figure 2. The phase statistics are plotted along with rotations of 360° to facilitate interpretation. These estimates suggest that the process is composed of two significantly different time-domain components, one component which dominates frequencies from $f = 0$ to $f = 0.23$ and the other component dominating frequencies from $f = 0.23$ to $f = 0.5$. The low frequencies may be thought of as representative of a smoothly varying basic component of the series while the high frequencies represent the more reactive, short-run influences in the market. Thus, the long-run structural component is perfectly out-of-phase with no time delay. Long-term decreases in quantity are matched by corresponding increases in price. The short-run reactive component doubtless reflects the more immediate adjustment of quantity to prevailing price. Use of the tau statistic indicates a lag of quantity to prices of about nine months, that is, quantity supplied is reacting to price change with a lag of about nine months. Thus, the long-run structural component is identified as the response of price to quantity and the short-run reactive component as the response of quantity to price.

The coherence and gain statistics for these series are given in figures 3 and 4 respectively. The highest coherence is at the very low frequencies and at the seasonal frequencies, especially the six-month frequency. Even under conditions of low coherence, however, straight line segments of the phase diagram generally reveal the correct direction of lead and lag (Granger and Hughes, p. 94). The most significant information in the gain diagram is found in the seasonal frequencies. Seasonal fluctuations in price are apparently somewhat smoothed from the more violent seasonal fluctuations in quantity. This result can be attributed to smoothing forces in the marketing mechanism operating on beef prices at this level.

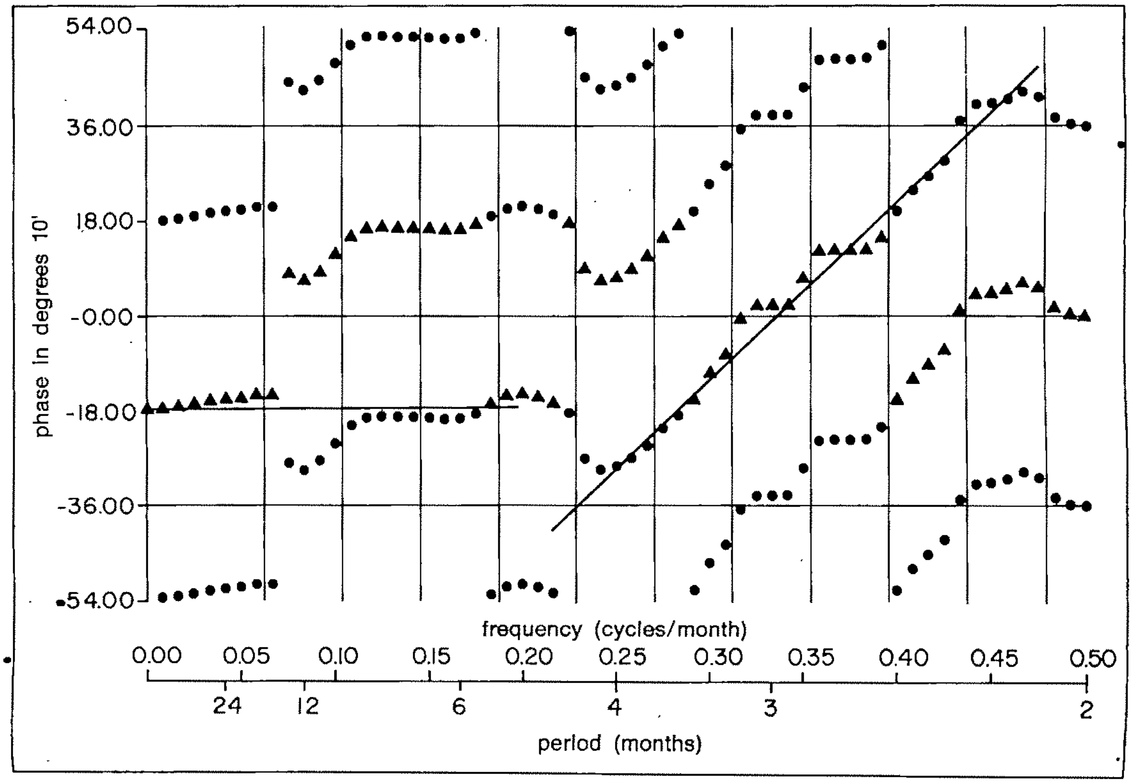

Figure 2. Phase diagram: cattle slaughter–live animal prices, 1949–72. See legend for fig. 1.

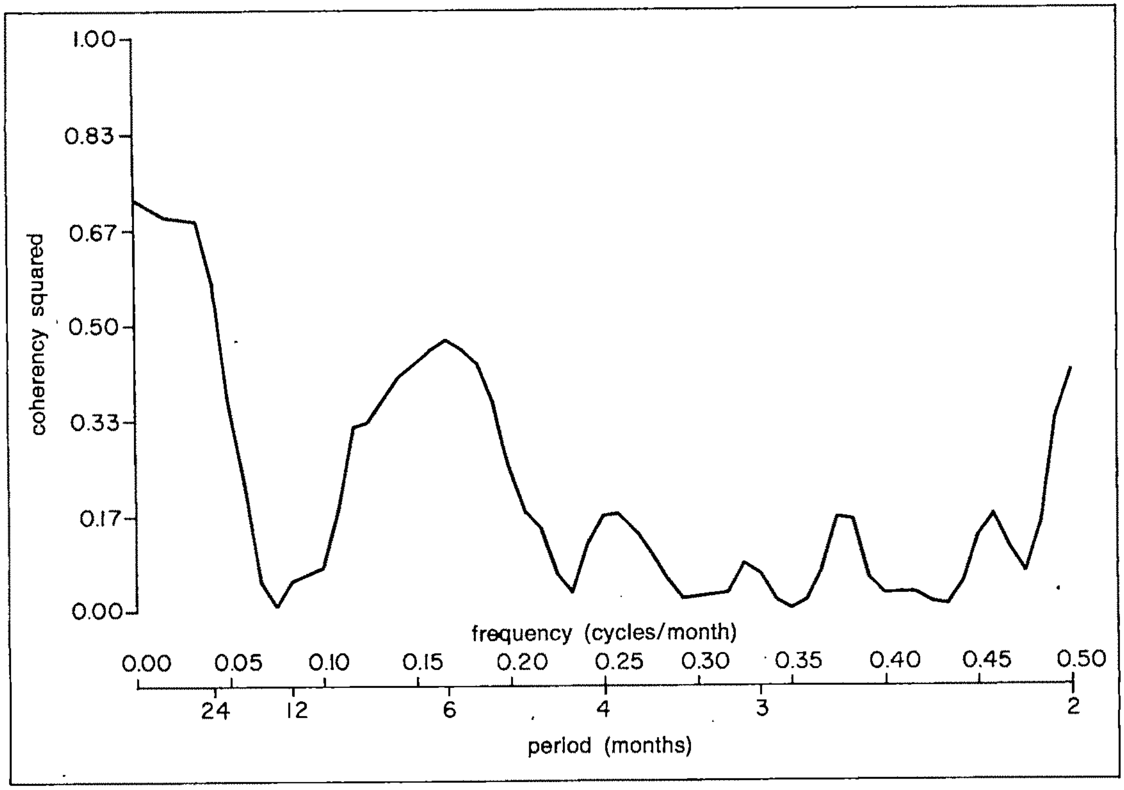

Figure 3. Coherence diagram: cattle slaughter–live animal prices, 1949–72

Causality and Feedback

Interpretations given the phase estimates indicate that wholesale prices lead retail prices at all frequencies. However, the lead-lag relationship between prices and quantity is structurally different when viewed at the higher and lower frequency bands. Specifically, a negative relationship exists between price and quantity without any time lag over the lower frequencies, while price leads quantity over the higher frequencies. These conclusions are further confirmed by the results of a causality test proposed by Granger and Hatanaka (p. 118). The test is developed from the notion that X "causes" Y if predictions of Y from all past information are superior to predictions of Y from past information exclusive of X. Feedback exists when both X causes Y and Y causes X. Operationally, predictions are obtained from a mixed autoregressive-moving average scheme using lagged values of X and Y. The test statistic under the hypothesis that X does not cause Y is

$$\Psi^2 = (N - m - 2) \log_e [\hat{V}_y(y)/\hat{V}_y(y, x)],$$

where N is the series length and m the number of lags in the prediction equation. $\hat{V}_y(y)$ is the estimated variance of the prediction residuals using past Y, and $\hat{V}_y(y, x)$ is the corresponding statistic using both past X and Y. The distribution of Ψ^2 is approximately chi-square with m degrees of freedom. If X helps predict Y, $\hat{V}_y(y)$ will be large relative to $\hat{V}_y(y, x)$ leading to large values of Ψ^2 and, consequently, rejection of the no causality hypothesis.

The causality test rejects the hypothesis that wholesale prices do not cause retail prices. For lags up to length 12, 24, and 48, the test statistic was 127.14, 148.03, and 158.98, respectively, exceeding the corresponding 0.05 critical values of 21.026, 36.415, and 60.882. The hypothesis that retail prices do not cause wholesale prices cannot be rejected at the 0.05 level, however, since the Ψ^2 statistic had values of 13.43, 22.53 and 58.79.

The price-quantity structure is consistent with feedback. The hypothesis that prices do not cause quantity is rejected for all lags at the 0.05 level (Ψ^2 = 84.12, 72.84, and 83.54). The hypothesis that quantity does not cause prices is also rejected at the 0.05 level for lags of length 48 (Ψ^2 = 71.40) and at the 0.10 level for lags of length 12 and 24.

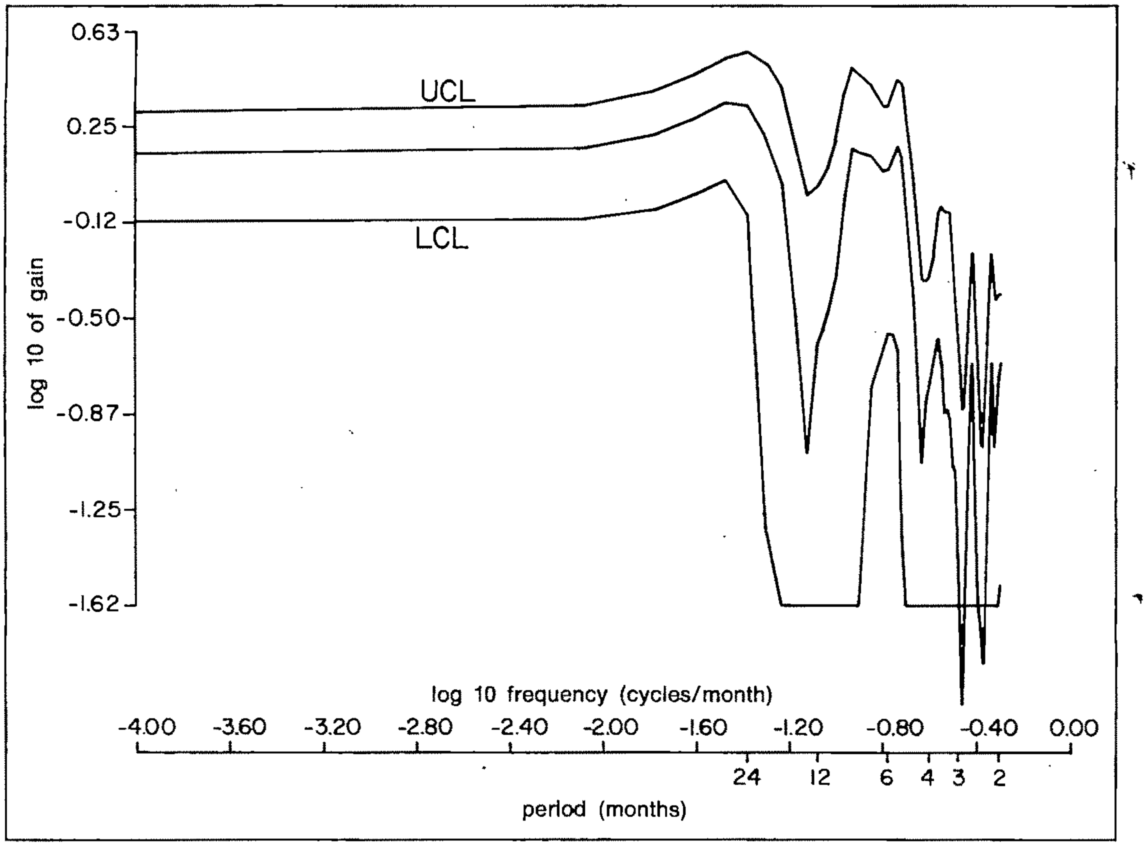

Figure 4. Gain diagram: cattle slaughter–live animal prices, 1949–72. UCL refers to upper confidence limit; LCL refers to lower confidence limit.

While the causality tests used here are calculated independently, the analysis of phase and coherence statistics provides a complementary insight into causality structure. The strength of causality is directly related to coherence (Granger and Hatanaka, p. 123). Furthermore, the phase diagram may be expected to show the direction of causality as it varies over frequency bands. For example, one-way causality between retail and wholesale prices is indicated by the near constant slope in the phase diagram over all frequencies. However, the causality of quantity by prices comes from the high frequency band, while the low frequency band suggests a near instantaneous causality of prices by quantity. Consequently, feedback which is difficult to characterize by traditional time-domain techniques becomes clearer when spectral techniques are used, if the reverse causation occurs at different frequency bands, that is, slopes of different signs over high and low frequency bands not only suggest feedback but also indicate the direction of causation as a function of frequency.

The Seasonality of Beef Prices

The nature and extent of price variations differ from one market level to the next. For example, a well-defined seasonal pattern of fluctuation exists in both the supply and price of feeder steers. However, the supply and price of beef at the retail level are relatively constant from month to month. The spectral statistics computed suggest that most of the smoothing of beef prices occurs between the feeder and live animal markets. Thus, the smoothing of the seasonal variation in beef prices is largely accomplished through the feeding operations. This is in agreement with general knowledge in the industry (Larsen, p. 3). Furthermore, the coherence at seasonal frequencies becomes lower at successive market levels, indicating almost complete price smoothing at the retail level.

Summary

The results derived from this analysis of beef prices at four different market levels—feeder, live animal, wholesale, and retail—are not consistent with estimates obtained by others using harmonic analysis. The spectral estimates indicate that prices at the feeder, live animal, and wholesale levels move together without any time lag and that retail beef prices lag prices at the other three levels by about three weeks. Therefore, it is concluded that beef prices are not established at the retail level.

Analysis of the timing relationship between price and quantity of beef at the slaughter level suggests that price and quantity are perfectly out-of-phase over the lower frequencies with no time delay. Thus, the long-term decreases in quantity are matched by corresponding increases in price. Over the higher frequencies, changes in prices lead changes in quantity by about nine months. Over the short run, changes in price do not bring about an immediate change in quantity. The supply of beef is relatively fixed over the short run. Producers are not in a position to stockpile the product for long periods and generally deliver their output to the market as it is ready for sale. The nine-month lag, over the short run, of quantity to prices apparently represents the time required (*a*) for producers to convince themselves that the price change is not a temporary phenomenon and to decide to divert a larger number of calves into the beef market and (*b*) for producers to feed out the additional calves that are diverted to beef production.

The spectral statistics also confirm that most of the smoothing of beef prices occurs between the feeder and live animal markets. Thus, the smoothing of the seasonal variation in beef prices is largely accomplished through feeding operations.

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Estimating the Returns to Information: A Gaming Approach

David L. Debertin, Gerald A. Harrison, Robert J. Rades, and Lawrence P. Bohl

A management game incorporating key decisions in corn and soybean production was constructed. Participants in an experiment were asked to play the game by making a series of decisions. Some of the participants in the experiment were denied access to research information and/or feedback from the previous decision. Results of the experiment indicated a significant positive return to both information and learning from feedback.

Key words: Corn, soybeans, management, information, learning, game, simulator.

The analysis presented in this paper is an initial empirical effort to quantify the benefits of research information and feedback to experimental "managers" of corn and soybean farms. The research was conducted in a laboratory environment. A management game incorporating key decisions in corn and soybean production was developed. Participants in the laboratory experiment, a group of novice farm managers, were asked to play the game by making a series of managerial decisions. One group of managers was denied access to research information. Another group was denied access to feedback from the previous decision. Profits generated by the game for individual "managers" were used to quantify the benefits of the information and feedback. Results of the laboratory experiment indicated a consistently significant positive return to both learning (feedback) and to research information for the novice farm managers.

Conceptual Framework

The idea that a manager's skills in coordinating resource use may be as important in determining profits as the amount of resources (land, labor, and capital) available is not new. Despite this fact, little is known about how the availability of information influences the profits of a firm.[1] Information can be thought of as an input in the managerial decision process. Additional information should lead to greater allocative efficiency in the use of other inputs if (*a*) the information is related to the decisions that the manager makes in operating the business, (*b*) the information can be obtained from sources readily available to the manager, and (*c*) the information is correct in that it leads the manager to the "right" decision. Increases in profit levels resulting from the availability of such information occur because other inputs are allocated more efficiently between competing uses and an allocative gain from selecting the right quantity of purchased inputs will occur (Welch, p. 45).[2]

This study was designed to test the hypothesis that profits are directly related to the availability of research information. It was

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[1] Leslie used a management game to study the impact of information on profits for managers of fluid milk plants. Haseley analyzed the relationship between information feedback and firm performance for food processing and marketing firms. Jones followed an experimental design similar to that presented in this analysis for analyzing the effects of competitive environments on decisions by supermaket managers. Bohl estimated a learning curve (returns to feedback) for farm supply firm managers using a management game. A number of efforts to estimate the effect on profits of agricultural research on a more aggregated basis have been conducted. See, for example, Fishel and Griliches.

[2] Welch argues that an efficient allocation of inputs between competing uses and allocative gains from selecting the right quantity of purchased inputs occurs as a result of formal schooling. The authors argue that research and extension information as well as learning from the results of previous decisions can substitute in part for formal schooling. Hence, similar allocative gains can be attributed to research and extension information and feedback (learning) information.

further hypothesized that profits are related to the availability of feedback from the previous decision that is provided to the manager. Finally, a positive interaction between research information and feedback was hypothesized to exist.[3]

The Management Game

The Purdue University Corn-Soybean Production Management Game was used to assess the returns to feedback from the previous decision and research information. The game was designed to represent the operation of an Indiana grain farm over a five-year period and incorporated a number of management decisions basic to corn and soybean production. Decisions incorporated into the game included (*a*) the combination of corn and soybeans to be planted, (*b*) variety and row width selection, (*c*) fertilization levels, (*d*) planting and harvesting dates, and (*e*) moisture levels for artificial drying. Each decision included in the model was chosen because research or extension information (from Purdue and elsewhere) useful in making the decision was available.

The game was constructed such that each of the management decisions had an impact on gross returns, costs of production, or both. Relationships representing the operation of the grain farm were derived from a variety of sources. Cost and labor requirement data were obtained from previous linear programming models used widely in farm management extension. Published research findings by the Purdue Agronomy Department were a major source of data for the development of the model. Statistical tools were used to derive coefficients not readily obtainable directly from the research data. For example, ordinary least squares was employed to estimate parameters of Cobb-Douglas production functions representing corn and soybean response to fertilizer. These estimates were subsequently incorporated in the computer model.

Validation runs were conducted to insure that relationships in the model were consistent with relationships that would be expected on an Indiana grain farm. Marginal concepts formed a primary basis for the evaluation. For example, the model's results were examined to determine if production functions incorporated into the game exhibited marginal returns to fertilization within the relevant range consistent with agronomy farm data and other computer models used in farm management extension at Purdue.

Additional sensitivity runs were made in an attempt to isolate the impacts of a selected change in each decision variable. Each sensitivity run was examined to determine if results were consistent with what is known in the real world of the impact of the decision variable. In addition, results from the simulator were compared with optimizing solutions generated with extension linear programming models. Although such a testing procedure did not prove that the model was a completely valid representation of an Indiana grain farm, it was felt that the model approximated a grain farm with detail sufficient for the subsequent experiment. Complete documentation of the game can be found in Debertin, Harrison, and Rades.

The Laboratory Experiment

An analysis of variance experiment was conducted with the management game. The fifty-two participants in the experiment were students in a senior level course in farm management. They were quite familiar with corn and soybean production practices. Seventy-three percent of the students were farming alone or in partnership. Most participants in the experiment could be thought of as being well-educated, beginning farmers. Additional characteristics of participants are summarized in table 1.

Each participant in the experiment was re-

Table 1. Characteristics of Participants in the Experiment

Average semesters of college work completed	7.3
Average grade point (6.00 = A)	4.8
Percent who were reared on a farm	94.2
Percent not currently farming	26.9
Percent farming alone or with relatives	73.1
Percent who intend to return to farm after graduation from college	76.9
Percent who had never grown corn nor soybeans	9.6
Percent who had grown corn but not soybeans	15.4
Percent who had grown soybeans but not corn	1.9
Percent who had grown both corn and soybeans	73.1

[3] It is recognized that marginal returns to additional information and feedback certainly depend on initial levels of information and feedback. Few decision makers in the real world have access to no information or no feedback at all. To this extent, the experimental design may have been less than realistic.

quired to operate a 600-acre farm located in Tippecanoe County, Indiana, that was suitable for corn and soybean production. All participants were asked to complete decisions for each of the five decision periods with access to no information other than the characteristics of the farm (i.e., acreage, soil tests, owned machinery) and April 1 corn and soybean prices. Participants were then arrayed on the basis of the total profits generated for the five years. The array was divided into groups of four individuals. Each individual in the groups was randomly assigned to one of four treatments. The experimental design insured that the managerial ability, as measured by the results of the initial decisions, was distributed to each treatment group and made meaningful comparisons possible.

All participants in the experiment were again given access to characteristics of the farm including acreage, soil tests, and owned machinery. Since the simulated farms were assumed to be located in a single county, all farm managers playing the game were confronted with the same set of weather conditions in a decision period. However, weather conditions changed (often substantially) between decision periods. Prices used in the game were actual historical data for the five-year period 1968–72. Managers were told only that they would be confronted with a set of prices which might prevail over a five-year time period. All participants were given cash prices of corn and soybeans as of April 1, as well as prices of futures contracts on April 1.

Feedback supplied to two treatment groups consisted of the results from the decisions of the previous year (period). Feedback given to participants was similar to information found in a detailed set of farm records. Included in the feedback were yields per acre, prices received, harvest moisture, hired labor, machinery, fertilizer, herbicide, and other variable costs, taxes on land, and interest on borrowed capital.

Information supplied to two of the treatment groups consisted of research data obtained largely from the Purdue Agronomy Farm. As part of the research project, an information retrieval system was developed. Tables of research data were stored on a magnetic disc unit. Each of the tables of information was useful in making one or more of the management decisions in the game (table 2). Participants in the experiment in groups having access to information were allowed to retrieve the tables of information as required by using a system of key words through a remote computer terminal (teletype).

Table 2. Tables of Data Available to Participants in the Experiment Having Access to Research Information

Purdue University Agronomy Farm Soybean Test, two-year average, 1971–72
A comparison of per acre variable and fixed costs for 4-row and 6-row corn and soybean production
Relation of row width and location to yield of corn grain, 1966–68
Estimated yield advantage for narrow row soybeans
Effect of potassium and phosphorous placement and rate on per acre yield of corn and soybeans
K_2O and P_2O_5 recommendations for various yield levels of corn and soybeans at different soil test levels
Corn response to nitrogen fertilizer, 8-year average
Soybean yields at different planting dates, 1966–68
The effect of planting date on corn yield, 1961–69
Returns to drying corn and soybeans at alternative market prices
Relationships between corn moisture, harvest date and yield loss

A reward system helped insure a willingness on the part of the students to do their best in managing the simulated farm. Each student was paid $10 for participating in the experiment. In addition, prizes of $25 were awarded to the students with the largest total profits for the five decision periods in each of the groups.[4] Students in each of the groups were told not to share feedback or research information with members of the other groups. Each of the groups met to obtain information and feedback and make decisions at separate locations. The authors concluded that little, if any, information was exchanged between treatment groups. Competition for prizes within treatment groups insured that there was minimal trading of feedback information among students within treatment groups. The authors concluded that the students made every effort to do a "good" job at making the managerial decisions consistent with the ex-

[4] Actually, only students in the last three groups competed for prizes. Data for the first cell in the experiments were obtained by asking fifteen of the students to complete a second set of decisions under the no feedback-no information condition. These students were then randomly assigned to one of the other groups and made a third set of decisions in competition for prizes. The amount of the cash awards was admittedly quite modest relative to rewards in the real world, and it may be argued that rewards should have been larger. However, the additional realism would have meant a substantial increase in the cost of running the experiment.

Table 3. Mean Profits Generated per Year for Each of Four Treatments, Five Years of Operation

Decision Period (year)	Treatment: No Information-No Feedback	Information-No Feedback	No Information-Feedback	Information-Feedback
1	−3,314	−1,316	−2,292	−504
2	11,978	16,554	14,094	19,316
3	13,814	19,553	17,787	25,267
4	343	5,021	4,099	7,177
5	20,475	24,235	25,990	28,073
Average of 5 years	8,659	12,810	11,935	15,866

perimental design and did not in any way attempt to sabotage the experiment. Interest in the experiment was very high among the students, and students were told of the research findings at the conclusion of the experiments.

Appraisal of Statistical Results

Mean profits generated per year for each of the four treatment groups over the five years of operation of the game are presented in table 3. Fluctuations in mean profit levels over the five years occurred primarily as a result of variation in prices and weather variables incorporated into the game.

Results of the analysis clearly show a consistently significant positive return to both feedback and information. The group with access to information and feedback was able to generate average profit levels nearly twice as great as the group with access to neither feedback nor information. Mean profit levels (table 3) were entirely consistent with hypothesized results for every decision period. An analysis of variance of net returns for individual participants was conducted (table 4). A separate analysis of variance was run for each decision period on the net returns for that decision period (not cumulative net returns). Hence, test statistics reported in table 4 reflect testing for differences in profits among treatments within a decision period.

For decision period 1, there was no feedback from the previous decision and accordingly the F-ratio for feedback was nonsignificant. Remaining F-ratios testing for the effects of feedback and information were significant at levels ranging from 0.25 to 0.005. F-ratios testing for interaction between feed-

Table 4. Analysis of Variance of Profits for Each Decision Period

Decision	Condition	F-Ratio	Significance
1	Feedback-No feedback	0.33	nonsignificant
1	Information-No information	1.42	0.250
1	Interaction-Feedback and information	0	nonsignificant
2	Feedback-No feedback	2.82	0.100
2	Information-No information	11.21	0.005
2	Interaction-Feedback and information	0.05	nonsignificant
3	Feedback-No feedback	9.39	0.005
3	Information-No information	17.13	0.005
3	Interaction-Feedback and information	0.30	nonsignificant
4	Feedback-No feedback	7.04	0.025
4	Information-No information	12.46	0.005
4	Interaction-Feedback and information	0.53	nonsignificant
5	Feedback-No feedback	8.83	0.005
5	Information-No information	3.53	0.100
5	Interaction-Feedback and information	0.29	nonsignificant

Note: The model used on each of the five decision periods was

$$Y_i = \alpha + \beta_1 D_{1i} + \beta_2 D_{2i} + \beta_3 D_{1i} D_{2i} + e_i,$$

where Y_i = mean profits for the ith participant, D_{1i} = 1 if participant received feedback (0 otherwise), D_{2i} = 1 if participant received information (0 otherwise), and e_i = an error term satisfying the usual assumptions.

back and information were nonsignificant in every decision period. Hence, based on this experiment, both feedback and information exert a positive influence on total profits. Feedback and information together have an additive but not multiplicative impact on profits.

Concluding Remarks

From the evidence generated in the laboratory experiment, it is possible to show positive returns to research information and feedback in a laboratory environment. Empirical results provided encouraging statistical evidence to support the initial hypothesis that at least in a partial equilibrium setting, both feedback and research information are major determinants of profit levels for managers of simulated corn and soybean farms.

The group of students with access to information appeared to find the optimal decision more rapidly than did the group with access to feedback but no information. Individuals confronted with the feedback-no information condition appeared to grope for an optimal decision. A trial and error approach for the group was very evident. For example, even after several decisions had been made, many members of the group with feedback but without information were applying fertilizer to crops at rates that were far from optimal. Individuals in both groups with access to information "zeroed in" on fertilization levels that were nearly optimal very early in the experiment.

As might be expected, an examination of the data revealed that the greatest marginal returns to feedback and information occurred for the managers that generated very low profits under the no feedback-no information condition. These managers were able to make a substantial improvement when confronted with either feedback or information. There was little evidence of a positive return to feedback for those who had generated large profits without feedback or information. However, even those managers who generated large profits without information were able to generate greater profits when given the research information.

If farm managers in the real world behave similarly to participants in the experiment, the potential benefits of improved information delivery systems may be substantial. A number of participants in the experiment commented on the usefulness of having information on all phases of corn and soybean production readily available in one place. A remote computer terminal may prove to be a more effective means than traditional research and extension bulletins for making large amounts of research information readily available for use by farm managers.

While the preliminary results from the effort to estimate returns to research and extension information in a laboratory environment were encouraging, three caveats apply to the results presented in this paper. First, the authors recognize that participants were not experienced farm managers but were individuals who had relatively little previous experience in actually making managerial decisions. However, the authors contend that the use of novice rather than experienced farm managers for the experiment in no way invalidates the results presented in the paper. Whether research and extension information would be of equal value for managers who had been producing corn and soybeans for many years remains a hypothesis to be tested. Second, some, but not all, novice farmers have college educations. As suggested by Welch, a college education may have better enabled participants in the experiment to decode and use information in a decision-making framework. Following this reasoning, returns to information for beginning farmers presented in this paper are overstated. However, it might be alternately hypothesized that the value of research and extension information for beginning farm managers without college educations would be even greater than for the college trained participants in the experiment. Participants had no doubt been exposed to similar research and extension information in agronomy and agricultural economics courses prior to the experiment. As Huffman has implied, extension information may substitute for formal schooling.[5] Third, even though a great deal of time and effort was devoted to the development of a managerial game that represented the real world operation of a Corn Belt grain farm, there is no way to prove that the game functioned identically to the real world. Further, there is no way to prove that the

[5] Huffman's finding that education and agricultural extension are substitute sources of allocative efficiency lends credence to the argument that returns to research and extension information would be at least as great for novice farm managers without college training as for managers with college educations (p. 96).

participants in the laboratory environment functioned identically to the way they would function facing real risks in an actual social and political environment. In the real world, there are not only rewards but also substantial losses. Participants may well have been willing to pursue riskier strategies in the experiment than they would have in a real situation.

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Cost Rates of Extending Unemployment Insurance to Agricultural Employment

Joachim Elterich and Richard Bieker

This study uses the results of a regression equation for seventeen survey states to predict the cost rate of extending unemployment insurance (UI) to agricultural employment for each of the forty-eight contiguous states. The equation included work force and UI system variables as regressors. For the United States, the cost rate averaged 3.3% of taxable payroll and ranged from 0.8% to 8.5% among states. With hardly any exceptions, the extension of UI to agriculture will not threaten the solvency of states' UI trust funds.

Key words: unemployment insurance, agricultural labor, cost rates, funds solvency.

Historically, agricultural workers have been excluded from most social legislation in the United States since the 1930s, including unemployment insurance (UI). The UI system in the United States, which is financed by employers in the system, originated as part of the Social Security Act of 1935. The major objectives of the UI system were (*a*) employment stabilization of firms, (*b*) aggregate income maintenance in the economy in general, and (*c*) insurance against personal loss of earnings for individual workers (Eckstein, pp. 14–16). By 1938, all states had passed bills to be included in the cooperative Federal-State Unemployment Insurance Program, but agricultural employment was exempted from coverage.

Two major reasons were given for initially excluding agricultural workers from coverage. First, it was argued that the employment patterns in agriculture, viz., the large number of farms with small numbers of employees, made the program administratively unworkable for agriculture. In addition, it was argued that the seasonality of agricultural employment would result in large benefit payments which would threaten the solvency of the insurance system.

Agricultural employment has continued to be exempted from coverage until very recently. However, exclusion was challenged on the grounds that it is not equitable to hired agricultural workers vis-à-vis other wage earners. Still, discussions on extending UI to agriculture are dominated by concerns about the highly seasonal employment patterns that are assumed to characterize agriculture and the effects this will have on the costs of the UI system.

To provide some answers to the questions about the costs of extending UI to hired agricultural workers, the U.S. Department of Labor initiated a series of studies designed to estimate the costs of extending UI to hired agricultural workers in seventeen states.[1] These studies are summarized in Bauder, et al. and NE–58 Farm Labor Technical Committee (1973a, 1973b). The findings of these studies indicate that there is considerable variation from state to state. The cost rate (expressed as benefits paid out to insured workers as a percentage of their taxable payroll) in the seventeen survey states range from 0.76% to 6.71% (Elterich and Bieker 1973b, p. 18). This large variation makes it difficult to generalize about a single cost rate for the agricultural industry. Furthermore, because of this variation, the survey data are of little

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This paper is based on research performed under a contract with the Manpower Administration, U.S. Department of Labor. Subsequent work by the authors revealed a better data source, and suggestions by R. Emerson and anonymous reviewers led to the revised predictions, which in some cases differ from the ones reported earlier (Elterich and Bieker 1973b). The authors are also indebted to J. Holt, Pennsylvania State University, W. Bauder, Cornell University, B. Erven, Ohio State University, C. Fritsch, formerly Texas A&M University, and R. Rossi and M. Ishikawa, Manpower Administration, USDL for their valuable suggestions on an earlier draft. The authors wish to acknowledge the invaluable assistance in programming and statistical work by Linda Graham and Gary Wellmaker of the University of Delaware. Published with approval of the director of the Delaware Agricultural Experiment Station as miscellaneous paper 686, University of Delaware, Newark.

[1] For the purpose of this study, agricultural workers are defined as essentially those employed by firms with standard industrial classification codes 01 to 07.

benefit to those concerned with the cost of UI for hired agricultural workers in nonsurvey states.

The purposes of this paper are to develop a model to explain the variation in the cost rates among the survey states and to use this model as a basis for predicting the cost rates for nonsurvey states. In addition, the paper considers the impact of agricultural coverage on the UI funds of the different states.

The Model and Estimating Equation

The cost of extending UI to hired agricultural workers in any given state depends upon (*a*) the extent to which agricultural workers qualify for benefits, (*b*) the magnitude of their compensable unemployment, and (*c*) the level of benefits they receive when unemployed. These values are determined by the nature of the UI system of the state as well as the employment patterns of the workers.

To be potentially eligible for benefits during his benefit year, a worker must earn a specified amount in wages from employers covered by the UI system during his base period. If he earns sufficient wages during his base period, he may receive benefits during his benefit year provided he experiences one or more weeks of compensable unemployment. The amount of benefits he actually receives during his benefit year depends upon his weeks of compensable unemployment, the level of wage credits he has earned during his base period, and the benefit payment schedule of the state.

The cost of UI payments to workers is generally paid by employers.[2] For the first one to three years (depending on the state), new entrants into the UI system are taxed at a standard rate, regardless of the magnitude of unemployment experienced by their employees. After this initial period, employers are taxed according to the level of unemployment experienced by their employees. However, even when employers are taxed according to their experience rating, statutory maximum and minimum rates are established. The UI provisions vary considerably among states (Elterich and Bieker 1973b, pp. 22–34), and it is thought that this variation has an impact on the cost rate.

In addition to differences in the UI provisions, the composition of agricultural production with respect to farm size and type varies among states. This variation results in differences in employment patterns in the hired farm labor market.

The model for explaining the variation in the cost rate among states incorporates both variation in the UI provisions and variation in employment patterns in the hired farm labor market. Specifically, the following functional relationship is proposed:

$$C_i = f(UI_i, LF_i),$$

where C_i is the cost rate of the ith state, UI_i is a vector of UI system variables in the ith state, and LF_i is a vector of hired agricultural labor force variables in the ith state.

The cost rate is specified as

$$\frac{\text{benefit payments to hired agricultural workers}}{\text{taxable payroll of agricultural employers}} \times 100.$$

The present minimum coverage criterion for employers established by federal statute is employment of one or more workers for twenty weeks or more or a high quarter payroll of $1,500 or more. Data from the seventeen survey states indicate that there is little variation in the cost rate for agricultural coverage within a state over a broad range of coverage criteria (Bauder et al., p. 3.43). The cost rate used as the dependent variable is based on the assumption of universal coverage, i.e., all agricultural employers who hire one or more workers for at least one day are covered. The reference period for both the benefit and base periods is from July 1969 to June 1970. The values of the cost rates correspond to those reported by Elterich and Bieker (1973b, p. 18).

There are several limitations inherent in the assumptions under which these cost rates are computed. The most critical underlying assumption is that the *ex post* work-leisure choice of workers does not change as a result of UI coverage. While this question obviously cannot be resolved until after UI is extended to hired agricultural workers, research conducted by Emerson indicates that significant changes in the work patterns of interstate migrants would not change the cost rate appreciably. In addition, the computed cost rates assume that the additional administrative costs associated with agricultural coverage are

[2] In New Jersey and Alabama, the workers as well contribute 0.25% and 0.5%, respectively, of their gross wages as of August 1971 (U.S. Department of Labor 1971a, pp. T-4, T-5).

zero. This assumption is probably fairly reasonable for all states except those few in which hired farm workers constitute a sizable proportion of the total work force. In a study of the administrative feasibility of extending UI to agriculture, Fritsch found that the increased number of first payments associated with agricultural coverage in the survey states would be less than the increase actually experienced in the survey states between 1968 and 1969 without extending coverage to additional industry categories. It was further assumed that all insured workers qualified for benefits, i.e., unemployed workers were willing and able to work. For an exhaustive discussion of the assumptions underlying the computed cost rates, see Elterich and Bieker (1972, pp. 37–40, 1973c, pp. 32–35, 41–44).

There is little directly related research to draw on in choosing operational variables for the UI and labor force vectors. The following explanatory variables were selected as the "best" on the basis of their logical relation to the cost rate (C) and on the basis of their availability on the state level for all of the states.

UI System Variables

Qualifying requirements (high quarter or HQ). All states require that a worker earn a minimum amount of wages in covered employment during his base year or portion thereof or work a minimum number of weeks to qualify for UI benefits. The more restrictive these qualifying requirements, the more difficult it is to qualify for benefits, other things being equal.

Previous research (Elterich and Bieker 1973a, 1973b) has shown that provisions with respect to minimum amounts of annual wages and number of weeks of employment do not severely restrict the number of farm workers who can potentially qualify for benefits. However, provisions with respect to high quarter earnings do restrict the number of farm workers who can qualify for benefits. In addition, the relationship between dollar qualifying requirements and the proportion of workers who qualify for benefits probably is not linear. For example, a change in high quarter earnings necessary to qualify for benefits from \$75 to \$125 probably does not disqualify as large a proportion of hired farm workers as a change from \$150 to \$200. Hence, the variable used to denote minimum qualifying requirements is specified as a dummy variable (1 if the state has a high quarter qualifying requirement of \$150 or more, 0 otherwise). High quarter qualifying requirements for each of the states were obtained (U.S. Department of Labor 1971a, 1971b).

Benefit amount (BA). Other things being equal, states which are generous in their benefit payments will incur higher costs in extending UI to hired farm workers than states which are less generous. The maximum dollar amount per week in the benefit payment schedule (including a dependency allowance if applicable) is used to denote the generosity of the state's benefit payment schedule.[3] The values are taken from Elterich and Bieker (1973b, pp. 29–34) as adapted from the U.S. Department of Labor (1971a, 1971b).

Labor Force Variables

Seasonality of demand for hired farm labor (SD). Other things being equal, there is a direct relationship between the cost rate of extending UI to hired argicultural workers and the seasonality of agricultural employment. The measure of seasonality of agricultural employment used in the analysis for the year 1969 (U.S. Department of Commerce 1972a, table 28) is (# workers employed 149 days or less $\div$ [# workers employed 149 days or less + # workers employed 150 days or more]) $\times$ 100.

Year-round workers (YRW). Seasonal demands for hired farm labor in a state can be met by various combinations of regular year-round workers, local casual workers such as schoolchildren and housewives, and by interstate and intrastate migrants. The extent to which the seasonality of employment of farm workers corresponds to the seasonality of demand for labor in agriculture depends upon the extent of interfarm and interindustry movement of workers during the year. This of course depends upon the location and mix of employment as well as the availability of job market information. The extent to which the seasonality of employment for workers who do some agricultural work is reduced is

[3] Since less than half of the agricultural workers have dependents, the assumption was made to increase the weekly benefit amount by one-half the maximum possible allowance for dependents in those states where a dependency allowance exists. The logarithmic form gives a better fit than the linear form, indicating that the cost rate increases at a decreasing rate as the weekly benefit amount increases.

reflected in the proportion of agricultural workers who are employed year-round. The variable used to denote the seasonality of employment of farm workers (as opposed to seasonal agricultural demand for labor) is the proportion of farm laborers and foremen who were employed fifty to fifty-two weeks during 1969 (U.S. Department of Commerce 1972b, table 172). Other things being equal, the cost rate is expected to be related inversely to the proportion of workers who are employed fifty to fifty-two weeks.

Annual earings (AE). The amount of benefits a worker is eligible to receive if he becomes unemployed is positively related to his base period earnings. The median annual earnings of farm laborers and foremen for 1969 (U.S. Department of Commerce 1972b, table 57) is used as a proxy for base period earnings. It is expected that the cost rate is positively related to median annual earnings.

To fit the data statistically, several functional forms were tried for all of the continuous variables, including the logarithmic, semilog, linear, and quadratic forms. Given that only positive cost rates are permissible and based upon the coefficient of determination and t-statistics, the following equation gave the best fit:

$$\text{(1)} \quad \log C = -3.7057 - \underset{(0.0535)}{0.3986}\,HQ - \underset{(0.0028)}{0.0127}\,YRW + \underset{(0.4018)}{1.6147}\,\log BA + \underset{(0.0051)}{0.0182}\,SD + \underset{(0.0838)}{0.1947}\,AE,$$

$\bar{R}^2 = 0.85$, $SEE = 0.098$, $DF = 11$.

Standard errors of the coefficients are in parentheses.

States with "high" qualifying requirements have a cost rate 1.1 percentage points lower than states with "low" qualifying requirements, *ceteris paribus*. An increase of 1% in the proportion of the year-round farm workers decreases the cost rate by 0.35 percentage points, while a 10% increase in the weekly benefit amount, which is equivalent to $7, is associated with a 0.65 percentage point increase in the cost rate.[4] Finally, a 10% increase in the proportion of the seasonal demand for agricultural labor and a $1,000 increase in annual median earnings are each associated with approximately a 0.5 percentage point increase in the cost rate.

On the basis of the beta coefficients, the variable (HQ) used to denote qualifying requirements is the most important in explaining the variation in the cost rate (beta = 0.79), followed by the proportion of seasonal demand (beta = 0.55), the variable used to denote the generosity of benefit amount (beta = 0.45), the proportion of year-round workers (beta = 0.44), and median annual earnings (beta = 0.36).

Predicted Cost Rates and the Impact of Coverage on State UI Trust Funds

Based on equation (1) for the seventeen survey states, cost rates were predicted for each of the forty-eight contiguous states, the ten U.S. Department of Agriculture farm production regions, and for the United States. The predicted cost rates are shown in table 1.[5] Twenty-one states have predicted cost rates of less than 2%, sixteen have rates between 2% and 3.99%, and nine have rates between 4% and 5.99%. Only two states, Connecticut, a survey state, and Michigan, have predicted cost rates of 6% or more. About 70% of the survey and 80% of the nonsurvey states had a cost rate of less than 4%.

The cost rates for each farm production region were obtained by weighting the cost rates of states in each region by their taxable agricultural payroll.[6] The regional cost rates vary from 2% in the Northern Plains region to 4% in the Pacific region. The relatively low cost rates for the Northern Plains, Appalachian, Southeast, and Corn Belt regions can be explained by the relatively low median annual earnings and low benefit payment schedules. A combination of factors accounts for the high rates in the Pacific and Mountain regions. A low proportion of year-round workers, a high proportion of seasonal jobs and high annual earnings are contributing factors to the high rates in the Pacific region. In the Mountain region, a high proportion of sea-

[4] Changing the weekly benefit amount by 10% one standard deviation above and below its mean resulted in a 0.72 and 0.58 percentage point change of the cost rate respectively.

[5] The range of the independent variables of survey states covers with one exception (weekly benefit amount) the range of the values for survey states, thus lending further support to the predictions (Kmenta, pp. 239–42; Theil, pp. 122–23).

[6] Taxable agricultural payrolls for individual states were obtained by deflating U.S. Department of Agriculture cash wage estimates by an unpublished factor derived from Social Security records.

Table 1. Observed and Predicted UI Cost Rates by State and Region

State or Region	Observed Rate	Predicted Rate	Standard Error of Prediction[a]
Connecticut	6.71	8.5	2.5
Delaware	5.10	4.2	2.1
Maine	2.06	2.1	2.3
Maryland	1.54	1.5	1.7
Massachusetts	2.98	2.7	2.0
New Hampshire	2.40	2.0	1.8
New Jersey	5.81	4.5	1.6
New York	1.57	1.7	1.7
Pennsylvania	1.62	2.7	1.7
Rhode Island	5.09	4.8	2.2
Vermont	0.76	0.8	2.3
Northeast[b]		3.0	
Kentucky		1.6	2.1
North Carolina		4.8	2.7
Tennessee		1.2	3.0
Virginia		1.1	2.0
West Virginia	1.44	1.5	2.2
Appalachian[b]		2.7	
Alabama		0.8	3.4
Florida	3.11	3.3	2.7
Georgia		0.9	2.7
South Carolina		1.3	2.9
Southeast[b]		2.5	
Michigan		6.0	2.6
Minnesota	2.87	2.8	2.4
Wisconsin		1.2	3.8
Lake States[b]		3.3	
Illinois		2.3	1.7
Indiana		1.5	2.0
Iowa		1.6	1.9
Missouri		4.1	1.9
Ohio	4.22	3.5	1.8
Corn Belt[b]		2.6	
Arkansas		4.4	2.3
Louisiana		2.7	2.6
Mississippi		0.9	5.8
Delta States[b]		3.0	
Kansas		3.9	1.9
Nebraska		1.4	2.1
North Dakota		1.3	2.1
South Dakota		0.7	2.9
Northern Plains[b]		2.0	
Oklahoma		4.3	1.9
Texas	3.47	3.2	1.6
Southern Plains[b]		3.3	
Arizona		3.2	4.2
Colorado		6.3	2.0
Idaho		3.0	2.3
Montana		0.9	2.7
Nevada		2.9	2.1
New Mexico		1.0	2.1
Utah		2.7	2.4
Wyoming		1.2	2.4
Mountain[b]		3.5	
California		3.9	3.2
Oregon		3.6	2.9
Washington	4.56	5.3	2.7
Pacific[b]		4.0	
United States[b]		3.3	
17 study states		3.3	
31 remaining states		3.3	

[a] 80% confidence level.
[b] From the UI program point of view, the regional figures reported are meaningless since state funds are independent. However, they are shown in order to give a comparison between regions and the dominance of some states within a region.

sonal jobs and high annual earnings account for the high rates.

The cost rates presented represent the cost to covered employers of extending UI to hired farm workers. Exactly how the cost of coverage within a state will be allocated among employers depends on whether the cost rate is greater than the maximum statutory cost rate for agricultural employers. If the predicted rate is less than or equal to the statutory maximum, agricultural employers will pay the total cost of agricultural coverage. However, if the actual cost rate is greater than the statutory maximum, part of the cost of agricultural coverage will be borne by nonagricultural employers covered by UI.

In considering the cost rate of a new employer entering the UI system, two time periods need to be considered. For the first one to three years (depending on the state) of UI coverage, an employer's payroll is taxed at the current standard rate of assessment for newly covered employers, regardless of the unemployment experience of his work force. After this initial period, the employer's tax rate is based upon the unemployment experience of his work force. However, even under experience rating, minimum and maximum tax rates are established for all covered employers. Thus, under both the standard and experience rating tax rates, a covered employer can generate a net surplus or net drain on the fund. The concern of those who oppose agricultural coverage is that such coverage will result in a net drain on the states' funds and even threaten the funds' solvencies. The relationship between the standard and maximum statutory cost rates under experience rating and the predicted cost rate for 1971 by state and farm production region are shown in table 2.

Under the standard rate of assessment, some of the costs of agricultural coverage would have to be borne by nonagricultural employers in twenty states. In the remaining twenty-eight states, payments by agricultural employers into the fund would equal or exceed the benefits paid out to agricultural workers. For the twenty states in which the predicted cost rate exceeds the standard rate, the proportion of benefits that would have to be borne by nonagricultural employers exceeds 1% of the fund balance in only Colorado and Arkansas. The proportion of benefits that would have to be borne by nonagricultural employers ranges from 0.5% to 0.75% of the fund balance in three states. In the remaining states, the proportion of agricultural benefits that would have to be paid by nonagricultural employers is less than 0.5%.

If agricultural employers were taxed according to their experience rating, the cost of agricultural coverage would have to be borne partly by nonagricultural employers in twelve states. In the remaining states, the predicted cost rate is less than the statutory maximum rate under experience rating, and payments into the fund by agricultural employers would equal or exceed the benefits paid out to agricultural workers. For the twelve states in which the predicted cost rates exceed the maximum statutory rates under experience rating, the proportion of worker benefits that would have to be borne by nonagricultural employers ranges from 0.002% of the fund balance in Montana to 3.2% in Colorado. It exceeds 1% of the fund balance in only one state and 0.5% in only two states.[7]

Another way to evaluate the potential impact of agricultural coverage on state UI trust funds is to consider the size of predicted agricultural benefits relative to total nonagricultural benefits. Predicted agricultural benefits as a percent of total nonagricultural benefits paid in 1970 range from 0.36% in New York to 40.11% in Colorado. In seventeen states, predicted agricultural benefits were less than 2.5% of total nonagricultural benefits. Most of these seventeen states were located in the Northeast, Lake States, and Corn Belt regions. In eleven states, agricultural benefits ranged from 2.5% to 5% of nonagricultural benefits, and in eleven other states between 5.1% and 7.5%. All Northern Plains states fall in the latter category. In only nine states did predicted agricultural benefits exceed 7.5% of total nonagricultural benefits. These nine states are concentrated in the Mountain and Southern Plains regions.

[7] These relationships between agricultural benefits and fund balances are for the single year 1970. Of course fund balances vary from year to year with the rate of unemployment among insured workers. During years of relatively high unemployment, the fund balance is drawn down while during periods of relatively low unemployment, the fund balance is built up. The impact of agricultural coverage on the fund balance will vary with the fund level. However, when the lowest fund level between the years 1967–72 was substituted for the 1970 fund balance, the relationships between the agricultural benefits that would have to be borne by nonagricultural employers and the fund balance did not change appreciably. Under the standard rate of assessment and the lowest fund level during 1967–72, the percentage of agricultural benefits that would have to be paid by nonagricultural employers would exceed 1% in five states as compared to two states if the 1970 fund balance is used.

Table 2. Impact on Trust Funds of Extending UI to Agriculture under Universal Coverage, by State, 1970

State or Region	Proportion of Cost Rates: Standard to Predicted	Proportion of Cost Rates: Maximum to Predicted	Agricultural Benefits as of Total Benefits	Ratio of Agricultural Deficit or Surplus to Total UI Fund: Standard	Ratio of Agricultural Deficit or Surplus to Total UI Fund: Maximum
			%	%	%
Connecticut	0.32	0.32	2.63	−0.40	−0.40
Delaware	0.83	1.06	3.23	−0.15	0.05
Maine	1.28	1.75	3.56	0.27	0.73
Maryland	1.85	2.88	0.90	0.10	0.21
Massachusetts	1.02	1.55	0.51	[b]	0.07
New Hampshire	1.38	2.19	4.76	0.10	0.30
New Jersey	0.62	1.02	0.98	−0.13	[b]
New York	1.80	2.51	0.36	0.05	0.09
Pennsylvania	1.01	1.49	1.04	[b]	0.07
Rhode Island	0.57	0.84	0.79	−0.07	−0.03
Vermont	3.25	5.30	1.61	0.61	1.16
Northeast[a]	0.84	1.21	0.90	−0.01	0.06
Kentucky	1.69	2.63	2.80	0.24	0.57
North Carolina	0.57	0.99	13.92	−0.41	−0.01
Tennessee	2.20	3.25	1.21	0.22	0.41
Virginia	2.39	2.39	5.06	0.31	0.31
West Virginia	1.76	2.16	0.87	0.08	0.12
Appalachian[a]	1.23	1.72	5.27	[b]	0.24
Alabama	3.29	4.39	1.58	0.54	0.79
Florida	0.80	1.34	25.06	−0.52	0.87
Georgia	3.10	5.17	2.73	0.27	0.53
South Carolina	2.09	3.18	2.34	0.23	0.46
Southeast[a]	1.80	2.78	10.38	0.07	0.66
Michigan	0.45	1.11	2.17	−0.21	0.04
Minnesota	0.97	1.61	3.85	−0.02	0.47
Wisconsin	2.20	3.58	1.37	0.20	0.43
Lake States[a]	0.81	1.55	2.22	−0.07	0.21
Illinois	1.16	1.72	1.53	0.05	0.20
Indiana	1.85	2.19	1.52	0.10	0.14
Iowa	1.66	2.45	5.57	0.48	1.06
Missouri	0.66	1.00	4.90	−0.24	[b]
Ohio	0.89	1.35	2.24	−0.02	0.07
Corn Belt[a]	1.16	1.67	2.60	0.02	0.17
Arkansas	0.62	0.91	23.67	−2.81	−0.63
Louisiana	1.00	1.00	2.46	0	0
Mississippi	3.03	3.03	5.24	1.08	1.08
Delta[a]	1.01	1.18	8.09	−0.20	0.19
Kansas	0.70	0.70	7.36	−0.36	−0.36
Nebraska	1.86	1.86	6.93	0.68	0.68
North Dakota	3.31	3.31	6.12	4.81	4.81
South Dakota	4.11	5.62	7.12	2.07	3.05
Northern Plains[a]	1.80	1.96	7.07	0.54	0.65
Oklahoma	0.64	0.64	9.80	−0.74	−0.74
Texas	0.85	2.28	18.74	−0.27	2.31
Southern Plains[a]	0.77	1.41	16.39	−0.34	1.87
Arizona	0.83	0.90	20.17	−0.31	−0.19
Colorado	0.43	0.57	40.11	−3.21	−2.38
Idaho	0.91	1.71	11.00	−0.18	1.32
Montana	3.30	3.30	5.37	2.66	2.66
Nevada	1.05	1.05	2.69	0.03	0.03
New Mexico	2.62	3.50	2.96	0.70	1.08
Utah	1.01	1.01	3.32	[b]	[b]
Wyoming	2.38	2.38	9.94	1.47	1.47
Mountain[a]	1.07	1.28	14.15	−0.43	−0.03
California	0.79	0.94	7.05	−0.50	−0.13
Oregon	0.76	0.76	5.80	−0.30	−0.30
Washington	0.51	0.57	6.92	−0.57	−0.50
Pacific[a]	0.65	0.72	6.96	−0.49	−0.21
United States[a]	1.02	1.40	4.26	−0.10	0.18

[a] It should be pointed out that any regional figures reported here are meaningless from the UI program point of view, since state funds are independent. The regional figures are reported to obtain a summary view with respect to the different farm production regions.
[b] Value is smaller than |.01|.

Conclusions

The purpose of this paper was to develop a model to explain the variation in the cost of extending UI to agriculture among seventeen survey states and to use this model to predict the cost rates for nonsurvey states and regions. In addition, the paper considered the impact of agricultural coverage on the UI funds of the different states. The regression model included work force and UI system variables as regressors.

On the basis of the model, the overall U.S. cost rate was predicted to be nearly 3.3%. Thirty of the forty-eight states had a predicted cost rate between 0.7% and 3%, while sixteen states had a rate between 3% and 6%. A rate of more than 6% was predicted for only two states.

In twenty-eight states, agricultural benefits amount to less than 5% of all benefits, thus not contributing an appreciable share. Twenty of the states will feel a marginal negative influence on their trust funds in the short run after UI is extended to agricultural workers. However, it is expected that in only two states would the fund experience a deficit of more than 1% due to the inclusion of agricultural workers under the standard rate of assessment. Considering the intermediate run and applying the maximum rate of assessment, only twelve states remain deficit states because of agricultural coverage. All of them have a deficit of less than 1%. In states showing a surplus or deficit in UI funds due to agriculture's inclusion, rural development implications may be important with respect to income transfers in the aggregate sense from agricultural employers to nonagricultural employees or from nonagricultural employers to agricultural employees.

As a by-product, the study appears to confirm *a posteriori* that the selected survey states reflect U.S. conditions fairly well. That survey states represent all states is suggested by the fact that in only five states do the values of any independent variables fall outside the range of the survey states.

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Notes

Some Problems in Estimating the Demand for Outdoor Recreation

Kenneth E. McConnell

Increased pressures to provide realistic, empirical measures of value for outdoor recreation have generated considerable research dealing with the demand for outdoor recreation. The thrust of this research is to provide nonmarket measures of the value of recreational facilities which are comparable to market values for competing activities. Measurement of the value of recreational facilities has been beset by data shortcomings and theoretical problems, and, as indicated in an article by J. A. Sinden recently published in this *Journal*, some of the perennial research problems remain.

The purpose of this paper is to derive recreation demand functions consistent with utility maximization to address specific issues in empirical research. Outdoor recreation demand functions are used to make inferences about the consumers' surplus and, implicitly, about the social welfare derived from particular sites. Hence, it is important that the empirical research be as consistent as is feasible with the theoretical structure from which the concept of consumers' surplus is derived. In discussing the relationship between recreation demand functions and consumers' surplus, Cesario and Knetsch state that "whereas the assumptions of constant marginal utility of income over the relevant range and utility maximization are necessary, . . . they generally do not pose particular practical difficulties" (p. 700). This paper will demonstrate explicitly the practical difficulties implied by the assumptions of utility maximization.

This paper considers three specific issues in outdoor recreation demand: (*a*) the appropriate measure of the value of time as a cost of participating in outdoor recreation, (*b*) the logical units of measurement for a recreation activity when estimating demand functions via the travel cost method, and (*c*) the appropriate functional form of the outdoor recreation demand function, particularly the relationship between the price and income variables.

The Value of Time in the Demand for Outdoor Recreation

Since the work of Cesario and Knetsch, it has been widely accepted that the time required in traveling to the recreation site is as important a cost variable as the travel cost itself in determining the quantities demanded of outdoor recreation. As Brown and Nawas state, "Given the importance of increased distance on the negative factors of travel time and alternative recreational opportunities, the inclusion of a separate variable, such as travel time per distance zone, would appear to be needed" (p. 24).[1] The purpose of this section is to demonstrate that, for estimating demand functions consistent with utility maximization, the researcher should consider not simply the time in transit but the total time required for completing the recreation activity. The model developed here is not meant to describe reality completely. It abstracts from many important determinants of the demand for recreation in order to analyze the impact of the constraint on time. For this approach to be useful, recreationists must act as if they are constrained by the time available for them to recreate.

We begin with a simple statement of the general problem. Suppose the consumer chooses among n recreation activities, $r_j, j = 1, \ldots, n$, and a composite bundle of goods, x, so as to maximize the utility from the consumption of goods and recreation per unit of time. The consumer's choices are constrained by his income and the total time available to him. Let $U(x, r)$ be the utility indicator with r denoting an n-dimensional vector.

We will examine the case where the consumer can choose the amount of time he works and also the case where the time at work is fixed. Let w represent the amount of time worked. To include both work and recreation in the same time constraint, they must be converted to the same units. The quantity variable for the recreation activity, r_j, is measured in the number of trips of a specified length. Let a_j represent the number of units of time required to participate in one unit of r_j. Hence, a_jr_j is the total time required to consume r_j trips of outdoor recreation activity.

When the consumer can choose the amount of time to work, the time constraint is

$$(1) \qquad \sum_{j=1}^{n} a_jr_j + w = T,$$

where T is the total time available. If the consumer

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[1] The work of Gary Becker suggests that the total time spent in an activity is the appropriate measure of the opportunity cost of time. Empirical work in recreation, to my knowledge, has been limited to measuring the opportunity cost of travel time only.

cannot choose the amount of time he works, then the time constraint is

$$(2) \qquad \sum_{j=1}^{n} a_j r_j = T^*,$$

where T^* is the fixed amount of recreation time available. In each constraint, a_j is the amount of time required for one unit of r_j. For example, suppose that T is measured in days. If r_j is the number of day visits to the beach, $a_j = 1$. If r_k is the number of three-day camping trips, $a_k = 3$.

The consumer must spend within the constraints implied by the equation,

$$(3) \qquad F(w) = px + \sum_{j=1}^{n} c_j r_j,$$

where p is the price of the composite good, c_j is the net variable costs, including travel and transfer costs, of the jth activity, and $F(w)$ is the income generated by working w units of time. Solving equation (1) for time worked and substituting in equation (3), we can write the constrained maximand,

$$(4) \qquad U(x, r) - \lambda(px + \sum_{j=1}^{n} c_j r_j - F(T - \sum_{j=1}^{n} a_j r_j)),$$

where the consumer chooses the quantities of recreation activities and the composite good. Maximizing equation (4) with respect to r_j yields

$$(5) \qquad \partial U/\partial r_j = \lambda(c_j + a_j F'(w)),$$

where c_j is the travel and transfer cost of a trip, $F'(w)$ is the marginal earnings of a unit of work, and a_j is the number of units of work that the consumer must forego in order to enjoy one trip of recreation activity, r_j. Hence, $a_j F'(w)$ is the earnings foregone by enjoying a trip of recreation activity, r_j. It is the earnings over the whole recreation period, as indicated by a_j, the number of periods of work required by the recreation trip and not just the time in transit. The important conclusion is that the cost of consuming a unit (trip) of an outdoor recreation activity is the sum of travel costs and the value of earnings foregone over the entire trip.

Suppose that the recreationist maximizes utility subject to a fixed amount of recreation time, as given by equation (2), and a fixed income, denoted by y. Instead of equation (4), the maximand will be

$$(6) \qquad U(x, r) - \lambda(x \cdot p + \sum_{j=1}^{n} c_j r_j - y) - \mu(\sum_{j=1}^{n} a_j r_j - T^*).$$

The first order condition with respect to r_j is

$$(7) \qquad \partial U/\partial r_j = \lambda c_j + \mu a_j.$$

The multiplier, μ, is the marginal utility of recreation time. Let us define a variable m_T such that $m_T = \mu/\lambda$. Here m_T has the dimensions $\frac{\Delta \text{utility}}{\Delta \text{time}} \Big/ \frac{\Delta \text{utility}}{\Delta \text{income}}$ or ($\Delta income/\Delta time$). It follows that m_T can be interpreted as the opportunity cost of scarce recreation time, measured in dollars of income. It is the equilibrium value of an additional unit of recreation time in any recreational activity. Equation (7) can be written

$$(8) \qquad \partial U/\partial r_j = \lambda(c_j + a_j m_T).$$

It is useful to compare equation (8) with equation (5). According to equation (8), the cost of a unit of the jth recreation activity is travel costs (c_j) plus the scarcity value of time ($a_j m_T$) in income. It is important to note that even in the case where the consumer foregoes zero earnings, he still considers the scarcity value of time as part of the cost of the recreation activity because the time could have been used in other recreational activities.

The implications of this section can be stated in a general way. Let m_T be the marginal monetary value of an extra unit of time, be it earnings, $F'(w)$, or simply the dollar value of an extra unit of recreation time. Then the demand for outdoor recreation can be written

$$(9) \qquad r_j = f_j(c_j + a_j m_T, y).$$

Here y is money income and $c_j + a_j m_T$ is the unit cost of the experience, where the unit is a trip. Because $a_j m_T$ is included in the measure of unit costs, it is clear that understanding the opportunity cost of total time is important for accurate measures of the economic value of outdoor recreation.

Equation (9) has important implications for empirical research in outdoor recreation. With regard to survey questionnaires, it suggests the following questions.

(*a*) Could the recreationists have worked for pay during the period of the recreation visit?
  i) If no, proceed to question (*b*); $F'(w) = 0$.
  ii) If yes, how much could have been earned?

(*b*) What might the recreationist have done if not on this trip?
  i) If nothing, then $\mu = 0$ and $m_T = 0$.
  ii) If something, attempt to determine willingness to pay for second most favorable activity.

Significant responses to this series of questions would indicate that recreationists act as if their time were scarce. However, it is possible to obtain zero value for the opportunity cost of time for some people (i.e., $m_T = 0$), because it is probable that a zero value for m_T indicates some persons have no alternative source of earnings and will not use the time for other recreation activities.

Equation (9) also has important implications for the specification of the demand function. The traditional approach has been to estimate the parameters of the function:

(10) number of trips = f(travel costs, income, distance).

The distance variable in equation (10) has been used as a proxy for time in transit. Equation (10) has been difficult to estimate satisfactorily, however, because travel and transfer costs are often almost a linear transformation of distance. The results of this section suggest that the researcher should make estimates of the value of total time consumed on the recreation trip, add this value to the travel and transfer costs incurred, and estimate the parameters of the relation. A distance variable can be included in equation (9) to account for the different relative travel costs of substitutes faced by recreationists from different distance zones and to allow for the filtering affect of distance on information about a site. We can now write:

(11) number of trips
$= f(\text{travel costs} + \text{time costs, income, distance}).$

It should be observed that the distance variable in equation (11) has a substantially different interpretation from distance in equation (10).

We can conclude from this analysis that using the travel cost method on a given set of observations, while ignoring the opportunity cost of time, underestimates the marginal value of the recreation. Something can also be said about the estimates of the consumers' surplus when equation (10) rather than equation (11) is estimated. Suppose the model estimated is $r = c_1 b_1 + D b_2 + y b_3$, when the true relationship is $r = (c_1 + c_2)\beta_1 + D\beta_2 + y\beta_3 + u$, where c_1 = travel costs, c_2 = time costs, D = distance, r = recreation trips, y = income, u = random variable, b_j = least-squares estimators of β_j-β_j = true coefficients. Under fairly reasonable assumptions, it can be shown that $Eb_1 < \beta_1$.[2] Thus, on the average, the slope of the quantity of recreation consumed with respect to the price variable is underestimated when the opportunity cost of total time is ignored.

For the linear per capita demand function, underestimating the slope with respect to the price variable results in an underestimate of consumers' surplus.[3] Hence, we can infer that a demand curve derived from the travel cost method which ignores the opportunity cost of time will result in a downward biased estimate of the consumers' surplus from the site. For models of other functional forms (i.e., nonlinear), it is not possible to determine, on an a priori basis, the effect of the omission of the opportunity cost of time on the estimated slope of the demand function and the value of consumers' surplus.

The importance of this section is that it suggests that the recreationist may consider the cost of the total time spent on the recreation activity as part of the cost. This conclusion is at variance with the accepted role of time cost in a recreation activity, which has been limited to the cost of time in traveling to the site. The inclusion of the additional value of time changes the structure of the estimating equation as well as the nature of the information to be gathered by the researcher.

Units of Measurement for the Travel Cost Method

Researchers in the field of recreation economics have used several quantity measures in estimating travel cost demand functions. The most common units are trips, user-days, and user-hours. For example, in Sinden's work, the quantity of outdoor recreation demanded is "the number of hours of a specific recreation activity . . . per family member during the 12 months prior to the interview" (p. 62). For Burt and Brewer, "quantities of outdoor recreation services are measured in units of visitor days" (p. 826). Knetsch uses number of visits.

Basically, the two measures of recreation demanded are trips and user-days, user-days being merely a linear transformation of user-hours.[4] Deriving the demand functions from a utility maximization framework demonstrates that user-days are not an appropriate measure for the quantity of recreation demanded when using the travel cost method.

Utility maximization implies that

$$(12)\quad \Delta\text{utility}/\Delta\text{quantity} = \text{marginal utility of income} \cdot \frac{(\Delta\text{costs})}{(\Delta\text{quantity})}.$$

Researchers implicitly use a first-order condition like equation (12) to solve for quantity as a function of marginal costs. It is clear, however, that in many cases the marginal cost of a user-day is independent of the level of travel costs, so that specifying the demand for user-days as a function of travel costs has no basis in theory.

A simple example will illustrate the difficulties of analyzing user-days with the travel cost technique. The costs of recreating can be divided into fixed costs per trip (travel costs) and net variable costs

[2] The bias from omitting c_2 is a form of specification bias. (See Ramsey.) It can be shown that $\beta_1 - Eb_1 = -[\beta_1/\sigma^2]$ (cov(c_1, c_2) var b_1 + cov(D, c_2) cov(b_1, b_2) + cov(y, c_2) cov(b_1, b_3)), where σ^2 is the variance of the error term. A priori income and time costs are likely to be highly correlated, while there is no reason to believe that cov(c_1, c_2) and cov(c_2, D) are non-negative. If these relations hold, the bias will be positive. If everyone's time is valued the same, c_2 is a constant and the coefficients are not biased. If the correct specification is nonlinear as implied in a subsequent section, the importance of the bias from a linear model is reduced.

[3] If $Eb_1 < \beta_1$, then $1/\beta_1 < 1/Eb_1$. Since $1/\beta_1$ is the slope of the demand curve with the price on the vertical axis, quantity on the horizontal axis, and $1/Eb_1$ its estimator, we can say that the true curve is more inelastic than the estimated curve. Consumers' surplus is derived by raising the price from zero until quantity becomes zero. Both curves begin at the same point on the quantity axis because the quantity taken at a zero price is known. Hence, the more inelastic curve yields the greater consumers' surplus.

[4] The variable user-days here is meant to include not only days on the site but also days consumed getting to the site. Researchers have not been consistent in this respect. Burt and Brewer include time consumed in reaching the site in their analysis of user-days whereas Sinden's measure of user-hours includes only time at the site.

per user-day times the quantity of user-days. Suppose that, for a particular recreationist, fixed costs per trip are \$10 and net variable costs per day are \$5. It seems clear that the recreationist will adjust his user-days in such a way that the marginal value of a user-day is \$5, as long as total conditions are satisfied. The marginal cost of a user-day is independent of the travel costs, once the recreationist has undertaken the trip. Hence, to be consistent with utility maximization, the demand for user-days should be estimated as a function of net variable cost per day including time costs.

The inconsistency of user-days with the travel cost method would not be a matter of concern if researchers did not use the resulting functions to derive measures of consumers' surplus. The computation of consumers' surplus requires knowledge of the per capita demand functions. The demand function is essentially a relationship between per unit cost and quantity demanded. The relationship between travel costs and user-days cannot truly be called a demand curve, even though it is possible to estimate such a relationship statistically.[5]

It is difficult to determine on an a priori basis what impact the inconsistency between user-day and the travel cost method would have on estimates of consumers' surplus because it is questionable whether the quantity estimated is really consumers' surplus. It seems likely that the more meaningful relationship between trips and travel costs is more inelastic than the relationship between user-days and travel costs because recreationists from the further distance zones are likely to reduce their trip numbers and expand their user-days per trip.

User-days are clearly important for many purposes. The capacity of a recreation site is best defined in terms of user-days per day. If one had good observations on net variable costs per day, including time costs which vary for individuals, it might be possible to estimate the demand for user-days.

The results of this section imply that the trip or visit is the most logical measure of quantity consumed in the travel cost method of estimating the demand for recreation. Analysis with user-hours or user-days may be appropriate in many cases. However, it does not appear logically correct to make inferences about consumers' surplus under the assumption that travel costs are the marginal costs of a user-day or a user-hour.

A Priori Specification of Outdoor Recreation Demand Functions

Since David Seckler originally raised the issue, there has been considerable discussion about the impact of income changes on the demand for outdoor recreation. An issue recently addressed by J. A. Sinden concerns the independence of the price and income slopes in the estimation of the demand model. Sinden compares the estimation of the following equations:

$$r_j = \beta_0 + \beta_1 c_j + \beta_2 y \tag{13}$$

and

$$r_j = \beta_0 + \beta_1 c_j \text{ for each income group.} \tag{14}$$

Here r_j is the number of visits, y is income, and c_j is a measure of costs, including time costs, of a visit. Referring to formulations exactly analogous to equations (13) and (14), Sinden states, "Despite a review of pertinent literature, no a priori reasoning could be developed to suggest that one equation would be more relevant than the other" (p. 65). If one assumes that outdoor recreation demand functions have been derived from utility maximization, a considerable amount can be said about the a priori specification of the demand functions.

The specific issue addressed by Sinden concerns the influence of income on the slope of the demand for recreation with respect to the price. This influence depends upon the functional form assumed. Since estimates of consumers' surplus vary greatly with the functional form of the demand curve, the issue is of more than passing interest.

The difference between Sinden's specifications, given by equations (13) and (14) above, is that for equation (13), the price slope is independent of the level of income (i.e., $\partial^2 r_j/\partial c_j \partial y = 0$). For equation (14), the price slope depends upon the level of income ($\partial^2 r_j/\partial c_j \partial y \neq 0$). Equation (13) is a special case of equation (14).

If one derives the income slope in a utility maximizing framework, it can be shown that

$$\partial r_j/\partial y = \sum_{k=1}^{n} U_{jk}^{-1} c_k / c' U^{-1} c, \tag{15}$$

where U_{jk}^{-1} are the elements of U^{-1}, the inverse of the matrix of the second-order derivatives of the utility functions, and c is the vector of all costs and prices faced by the recreationist.[6] It is clear from equation (15) that the income slope depends upon the costs (c) for all specifications of the utility function. Hence, $\partial^2 r_j/\partial c_j \partial y \neq 0$ and by the symmetry of

[5] The relationship can be estimated statistically because raising travel costs reduces the number of trips. With fewer trips, the number of user-days declines also because recreation time for most people occurs only with days off from work, weekends, and vacations.

[6] Assume that c_j includes the travel and transfer costs and time costs per unit of the jth activity and that those costs are constant. For simplicity of notation, we can drop the composite good, x, from the analysis. Then differentiating the first-order conditions, equation (5), with respect to income gives

$$\sum_{k=1}^{n} U_{jk} \frac{\partial r_k}{\partial y} - c_j \frac{\partial \lambda}{\partial y} = 0 \quad j = 1, n$$

and

$$-\sum_{j=1}^{n} c_j \frac{\partial r_j}{\partial Y} = -1,$$

or in matrix form, where U_{jk} is the matrix of second-order partials

cross partials, $\partial^2 r_j/\partial y \partial c_j \neq 0$. The price slope depends upon the level of income. We may conclude that the more general specification, equation (14), is more in keeping with utility maximization. Demand analysis which has as its goal inferences about consumers' surplus should deal with demand functions which permit the price slope to vary with the income level.

The attempt to make the functional form of empirical demand functions consistent with utility maximization has important implications for policy. First, for any given distribution of income, a different functional form for the demand curve implies a different value for the consumers' surplus. Second, as Stoevner and Brown pointed out for a particular case (p. 152), some nonlinear specifications imply that estimates of consumers' surplus change as the distribution of income changes. Keeping demand functions consistent with utility maximization will give analysts a common point of departure.

In sum, there is a priori reason to specify the econometric structure of a demand model in such a way that the price coefficient may vary as income varies. The a priori specification implied by utility maximization precludes additive functional forms. The result is important because it permits analysts to determine which demand functions are not consistent with utility maximization, instead of assuming consistency in all cases.

This paper has developed an analysis of the demand for outdoor recreation in a utility maximization framework for the purpose of analyzing empirical issues of research in outdoor recreation economics. The three basic conclusions of this paper are (*a*) that the appropriate time variable in the demand for outdoor recreation is the value of the total time consumed by the recreation activity rather than simply the time in transit, (*b*) that the unit of measurement consistent with the travel cost method is the trip or visit and not user-days, and (*c*) that there is a priori reason to specify the demand function such that the price slope can change as income changes.

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of the utility function and $\partial r/\partial y$ is the vector of income slopes,

$$\begin{bmatrix} U_{\mathfrak{R}} & -c \\ -c' & 0 \end{bmatrix} \begin{bmatrix} \dfrac{\partial r}{\partial y} \\ \dfrac{\partial \lambda}{\partial y} \end{bmatrix} = \begin{bmatrix} 0 \\ -1 \end{bmatrix}.$$

By the rules for inverting a portioned matrix, it can then be shown that

$$\begin{bmatrix} \dfrac{\partial r}{\partial y} \end{bmatrix} = \begin{bmatrix} A, & -U_c^{-1}(c'U^{-1}c)^{-1} \end{bmatrix} \begin{bmatrix} 0 \\ -1 \end{bmatrix},$$

where A is a matrix occupying the first n by n places of the inverse and $-U^{-1}c(c'U^{-1}c)^{-1}$ is a column vector occupying the $n + 1$ column of the inverse. Solving for any particular $\partial r_j/\partial y$ yields the expression given in the text. This result implies that a demand function of the form $r = g(c) + h(y)$, when $g(\cdot)$ and $h(\cdot)$ are arbitrary functions, is not consistent with utility maximization.

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Implications of Uncertainty for the Measurement of Efficiency

E. C. Pasour, Jr. and J. Bruce Bullock

Economists often find themselves in a position of evaluating the efficiency of existing situations. These situations range from the operation of individual firms to the organization and operation of entire economic systems. French indicates that U.S. Department of Agriculture and state experiment station economists have published more than 700 research reports and journal articles since World War II concerned with efficiency in the processing and marketing of agricultural products.

The measurement of efficiency appears to be a more difficult task, both conceptually and operationally, than has generally been recognized. The difficulties arise because of the inability of researchers to define the "optimal" situation in a world of uncertainty.

The purpose of this paper is to discuss the problems posed by uncertainty and information as a scarce resource in analyzing the efficiency of existing firms and markets. The limitations of efficiency measures which exclude uncertainty and information are analyzed and the implications for research are briefly discussed.

Efficiency Norms

This paper considers a situation to be efficient when the decision maker has no preferred alternative, given the circumstances. Efficiency is a relative concept. Hence, judgments about the efficiency of an observed situation can be made only by comparing the observed situation with some defined efficiency norm. More specifically, selected characteristics (costs, price differentials, etc.) of the observed situation are compared with the same characteristics of the norm.

Norms for firm efficiency studies are often defined using economic-engineering techniques. The characteristics of a perfect market in time, space, and form are often used as the norm in examining the efficiency of a marketing system. These norms have a common characteristic. They assume that decision makers have perfect knowledge about all relevant variables. Moreover, the cost of obtaining this information is assumed to be zero.[1]

Divergence between the characteristics of the observed situation and the norm is often interpreted as being a measure of the efficiency of the observed situation relative to the norm. Thus, the observed situation is said to be efficient if there is no difference between the selected characteristics of the observed situation and the norm. The wider the divergence between the observed and the norm characteristics, the more inefficient the observed situation is judged to be.

Efforts to measure and identify inefficiencies are based on the presumption that inefficient situations (as identified by the above criteria) are undesirable. Consequently, if a situation Y_i is judged to be inefficient relative to some norm (situation X), then the decision maker in control of Y_i should prefer situation X to situation Y_i. Moreover, if situation Y_i is inefficient, it will be in the interest of this decision maker to alter Y_i until the selected characteristics of his situation correspond to those of situation X. If we were to judge Y_i to be inefficient but concede that it is not in the interest of the decision maker to move from situation Y_i to situation X, then the measurement of inefficiency would provide very limited information. It is likely to be of little interest to the decision maker to know that he missed X (the norm) by 20% if he has no desire to arrive at X but prefers to remain at Y_i.

Thus, to measure inefficiency, the researcher must be certain that the defined efficiency norm is the goal that the decision makers are aiming at. Moreover, it is necessary that the norm account for all dimensions of the operating environment in which the decisions are made. The existence of uncertainty, costly information, and the interdependence of time periods are three dominant characteristics of this environment that cannot be ignored. Unless the efficiency norm incorporates optimal adjustment to these components of the problem it will be "impossible to claim that any specific organization [norm] will represent maximum economic efficiency or even that it will

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[1] These norms also assume that the world is free of externalities. The existence of externalities may cause a divergence between the socially optimal situation and the optimal situation as viewed by individual entrepreneurs. The efficiency norms discussed here are those used to evaluate the efficiency of firms or markets where decisions are based on maximization of a decision maker's objective function rather than a "social" objective function.

beyond doubt be more efficient than the existing organization" (Bressler, p. 67).[2]

Recognition of this dimension of the problem of measuring inefficiency casts serious doubts on the validity of efforts to classify observed situations as efficient or inefficient. Researchers are constrained to use norms that require perfect information to be optimal, but the entrepreneur must make decisions with imperfect information. There is no way to prove that situation Y_i is inefficient relative to situation X if X is the optimal situation only under conditions of perfect certainty and costless information. Use of a norm which assumes that a decision maker has perfect and costless information is likely to lead to an incorrect assessment of the efficiency of current production and marketing practices. Information, as is the case for any economic good, is scarce and costly.[3]

Divergence of the existing situation from the defined efficiency norm arises for one of two reasons. Either the existing system is in fact inefficient or the efficiency norm is incorrectly defined. Therefore, divergence of existing conditions from those specified by the efficiency norm is not sufficient evidence to judge the existing situation inefficient. Indeed, it is questionable if an inefficient (nonoptimal) situation would ever be observed where the decision maker is free to select and implement his own course of action. If the norm was contained in the set of attainable situations from which the decision maker selected his course of action, why would he ever select any other alternative? If he did not select the norm, it is necessary to question either the rationality of the decision maker or the validity of the norm. Problems posed by uncertainty and information costs in identifying inefficient market practices are discussed below for several different kinds of research.

Optimal Plant Size

A number of cost curves have been constructed by economists in an effort to define the optimal size production or marketing plant or firm. When information costs are considered, Friedman points out that one might expect not an optimum firm size but an optimum distribution of firms by size (p. 146). When each firm has specialized factors of production, no reason exists to expect a single optimum size of firm.[4] The specialized factor to a firm may relate to physical production inputs per se or to information concerning production or marketing activities. Much of the work concerned with optimal firm size assumes that firms have no specialized information (or other inputs) or that the value of such information is zero.

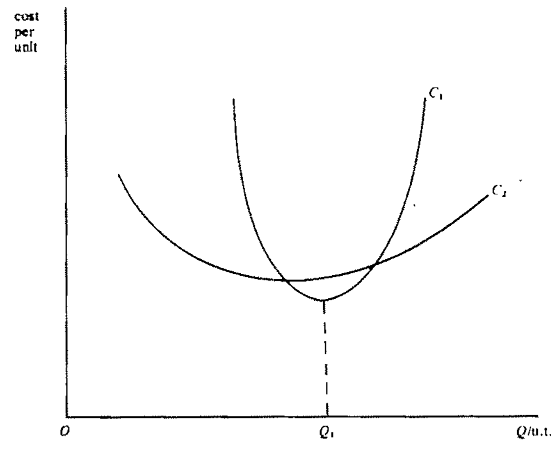

Figure 1. Effect on firm cost of uncertainty about output levels

For example, the development of empirical cost curves typically ignores (as Bressler suggested) any adaptability to uncertainty which the firm might make through plant flexibility. That is, a firm might intentionally incur costs to free itself from the restrictiveness of organizing production in the least cost way for a given rate of output. For example, the alternatives faced by a firm may be as depicted in figure 1.

C_1 and C_2 represent costs of producing a given product with alternative production facilities. The technology and plant organization having the cost indicated by C_2 is more flexible than that indicated by C_1.[5] If the firm expects to produce OQ_1 units of output, C_1 represents the cost of the least cost plant to produce this level of output. The above discussion indicates, however, that the entrepreneur may rationally consider the more flexible plant represented by the curve C_2 if he expects the rate of output to fluctuate considerably about OQ_1. That is, he may choose plant C_2 as an adaptation to uncertainty about the level at which the facilities will be operated. If the producer so chooses, there is no basis for concluding that such a situation is inefficient even though production costs are higher over some range of output than would exist if he had selected C_1 in the absence of uncertainty about the output level.

Spatial Equilibrium Models

The perfect market concept is used in spatial equilibrium models to provide a standard of com-

[2] However, Bressler did not see this as an insurmountable problem for economists. "While it should serve as a perpetual warning to researchers, it is far from being a demonstration that nothing useful can be accomplished" (p. 67).

[3] In a seminal article on the economics of information, Stigler develops the idea that additional search on the part of a prospective purchaser is rational as long as the gains exceed the costs. Thus, one would expect the optimal amount of search to vary with the opportunity cost of time and with the value of the item being purchased.

[4] "If we ask what size firm has minimum costs, and define 'minimum costs' in a sense in which it is in a firm's own interests to achieve it, surely the obvious answer is: firms of existing size" (Friedman, p. 146).

[5] Flexible here means that fluctuations in the rate of output about Q_1 cause smaller changes in per unit cost than for the facility represented by C_1.

parison for the pricing and distribution of a product. Market inefficiency is measured against a norm which implicity assumes that information costs are zero. Such models determine the least cost allocation based on information available *ex post*. Since the decision maker does not have the same information to use in making his decision, it does not seem appropriate to say that the decision actually made (the actual allocation) was suboptimal.

In his study of the U.S. coal industry, for example, Henderson took observed deviations of actual flow patterns from those defined by the model to calculate that the industry was only 88.2%, 79.1%, and 81.9% efficient for the years 1947, 1949, and 1951. It is not possible to conclude from the results of such studies that there are, in fact, allocative inefficiencies. The computations made of inefficiencies in shipping patterns implicitly assume a zero value for information and for the value of diversification of markets by shippers as a hedge against price uncertainty. Yet, diversification is a form of insurance and people willingly pay for many kinds of insurance coverage. This conclusion does not imply that spatial equilibrium studies are not useful. It does suggest that the cost information from these studies should be viewed as simply that and not taken to represent all costs relevant to the optimal shipping pattern.[6]

Market Imperfections and Inefficiency

A market imperfection is often said to exist when price relationships in time, space, or form diverge from those defined by the perfect market concept. For example, a price difference for a product at a given location at two points in time which exceeds storage costs is often taken as *prima facie* evidence of a market imperfection. However, the concept of market imperfection loses its automatic implications of inefficiency when real world risk and information costs are considered.

The following example illustrates why market imperfections (as defined above) cannot be interpreted as *prima facie* evidence of inefficiency. The live price of fed cattle does not always reflect the "true" value of the animal.[7] However, it would be premature to conclude that the pricing system is inefficient in view of the nature and extent of the uncertainties involved.

Perfect information about the true value of the animal is not available at the time the live price is determined. The animal must be slaughtered before its cut-out value can be established. There is also uncertainty with respect to which retail prices to use in establishing the true value of the animal. Time lags involved with moving the meat from slaughter to retail sale dictate that retail prices existing at the moment of slaughter are not appropriate. The appropriate prices are those at which this meat will actually be sold. What can be said about the true value of the animal in the absence of perfect information about these prices?

The efficiency of the pricing mechanism cannot be judged by a simple comparison of live price and true value for each animal even if the true value of the animal could be measured unambiguously. Such a norm assumes that the optimal distribution of true value minus actual live price not only has a mean of zero but also has a variance of zero. This unrealistically assumes that there are no costs associated with reducing the variance of this distribution to zero.[8]

If the deviations of actual from true value are symmetrically distributed about zero and the cost of reducing the variance of this distribution exceeds its value to participants in the system, this would seem to describe a preferable situation to one with zero variance.[9]

Pricing of fed cattle on the basis of carcass weight and grade has been suggested as one way of reducing the variance. However, the industry has not adopted this pricing procedure. If participants of the system are rational, their failure to adopt this procedure strongly suggests that perceived costs exceed the perceived benefits. Whatever the reason, "judgments" about increasing the efficiency of the system by pricing on the basis of carcass weight and grade require a measure of these perceived costs and returns.[10] As Stigler aptly states, "There is no 'imperfection' in a market possessing incomplete knowledge: information costs are the costs of transportation from ignorance to omniscience and seldom can a trader afford to take the trip" (p. 291).[11]

[6] In some situations, these studies do provide information useful in long-run decision making. For example, the Schrader-King study correctly anticipated rapid growth in Great Plains cattle feeding relative to growth in other areas.

[7] According to the idea of a perfect market, the "true" value of the live animal is the total value of the retail cuts (and hide, etc.) sold from the animal minus the cost of transforming and transporting the live animal to the point of final sale. Thus, the "true" value of the animal is its value *ex post* as determined by the consumer.

[8] "So the criterion of an efficient market becomes one with an appropriate frequency distribution of prices. A good deal of work is required on this problem, but none is required to reject the criterion of a single price of an efficient market" (Stigler, p. 291).

[9] Assuming it is possible to define the value (*ex post*), one research approach would be to focus on determining if this distribution has a mean of zero and to focus on the costs and returns of reducing its variance.

[10] Irwin makes essentially the same point concerning the importance of information and other "intangible functions." He defines the intangible function as "(1) pricing, plus financing and risking, and (2) guiding products to consumers in place, form, and time. Thus, in the study of marketing costs, the popular tendency is to consider as excessive all charges beyond the costs of physical services (principally transporting, processing and storing), making little or no allowance for the costs of the essential intangible services" (p. 811).

[11] The concept of market imperfection as used by Stigler refers to an inefficiency in the marketing system. Problems arise in describing marketing imperfections in this context (as is the case for any inefficiency) under real world conditions of uncertainty and costly knowledge.

Conclusions and Implications

The concept of efficiency loses its precise meaning when one departs from the perfect market norm and begins to consider real world decisions which must always be made under conditions of less than perfect information. Economists have yet to describe efficiency under real world conditions of uncertainty where knowledge is costly to produce (Demsetz). Furthermore, the measurement of information and other transactions costs as a way of identifying inefficient firm or market decisions does not appear possible. As Cheung states, "In a world where every individual is asserted to behave consistently with constrained maximization, economic inefficiency presents a contradiction in terms. Even outright mistakes are traceable to constraints of some types. The world is efficient, if the model describing it sufficiently specifies the gains and costs to make it so . . . . Thus the world is inefficient only when the system chosen to analyze it fails to fully specify the gains and costs of every action described" (p. 71).[12]

What are the research implications? Many studies measure economic efficiency of current production or marketing practices against a norm which assumes away uncertainty and information costs. Such estimates are likely to be misleading. By ignoring relevant information costs, such estimates often explicitly and erroneously classify as inefficient activities that are indeed optimal for the decision maker. Even if a new and preferred arrangement by the entrepreneur is found, one can judge the existing arrangement inefficient only in an *ex post* sense.

A reviewer suggests that the norm selected is immaterial so long as the researcher recognizes it as a norm and not a goal. Arbitrary norms, however, cannot be used as meaningful standards for measuring the efficiency of firms or markets if a situation is considered to be efficient when the decision maker has no preferred alternative. To conclude that firms or markets are inefficient because of imperfect knowledge or uncertainty is to say little more than that decision makers would select other choices if uncertainty and imperfect knowledge were not facts of life. Since information is scarce and cannot be obtained at zero cost, firms and markets operating under real world conditions will yield different outcomes than those implied by the perfect market norm. There is no reason to expect (or way to prove) that a preferred outcome was attainable by the decision maker, given the circumstances.

The fact that "efficiency studies" cannot prove that firm or market results are inferior relative to an attainable alternative does not mean that such studies are useless. *Ex post* studies of firm and market results may provide information useful to the entrepreneur in making future decisions concerning costs and returns of alternative production and marketing techniques.

Problems posed by imperfect knowledge in describing efficiency under real world conditions does not mean that the operation of firms or markets cannot be improved. The profit-maximizing entrepreneur is constantly groping for arrangements which will decrease costs and increase net returns. Information provided through public or private channels can often alter the most profitable arrangements. A change in public policy which decreases the cost of product information, for example, might change the optimal amount of search by the decision maker. Similarly, a decrease in the cost of information to a producer, whether provided through public or private channels, might bring about a change in level of input for a crop or livestock producer or processor. Information can be provided to the firm in its search for a preferred arrangement, but it can never be known for sure that a better outcome is available to the individual entreprenuer.

Efficiency is a widely used concept. If information were not scarce or costly, it would be easy to describe and identify inefficient activities. A meaningful efficiency concept, however, has yet to be defined for a world characterized by uncertainty, imperfect knowledge, and costly information.

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[12] This closely parallels Frank Knight's statement that "it is true and important, if unfortunate, that scientific explanation of what is demonstrates that it is inevitable under the given conditions . . ." (p. 143).

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Some Implications of the "New Theory of Consumer Behavior" for Interpreting Estimated Demand Elasticities

Thomas F. Hogarty and Robert J. Mackay

Problems of interpreting price elasticities of demand have been explored, both explicitly (Manderscheid) and implicitly (Purcell and Raunikar), in articles in this *Journal*. This note examines a problem not considered in these discussions. Specifically, we analyze some implications of the recent developments in the theory of consumer behavior for the estimation and interpretation of demand elasticities.

Existing Knowledge

Given temporal fluctuations in the prices of agricultural goods, existing theory and evidence suggest irreversibility of demand, i.e., consumers' response to price reductions exceeds their response to price increases. As described by Goodwin, Andorn, and Martin, "During a period in which prices of a product decrease . . . as a result of some change(s) in the conditions of supply . . . people form the habit of consuming the product at a certain rate. In the following period of reverse condition (also persisting for a long-run period) people reduce their consumption of the product, but at a rate lower than that at which it was increased" (pp. 9–10).

Note that this behavior contrasts sharply with the predicted behavior of producers. Quoting again from Goodwin, Andorn, and Martin,

> The response relationship on the supply side [output response] describes what will happen to the quantity offered for sale when [there is] . . . some particular change in price. *The reason for the irreversibility of output response is that once advanced technology has been adopted by producers it will rarely be given up.* Thus, in a phase of decreasing prices the quantity offered for sale will decline, but at a rate less rapid than the rate of expansion during a phase of increasing prices. . . . To summarize the similarity between the two concepts of output response and consumption response, "output response" is irreversible due to fixity of technology, while the "consumption response" is irreversible because of habit formation and the resistance to breaking habits once they are established. (Pp. 11–12, italics added)

The central theme of this paper is that the "output response" attributable to producers can also be observed in the behavior of households. This analogous response (*a*) is opposite in direction to the "consumption response" described above and may be permanent and (*b*) is graphically represented as a shift of, rather than a movement along, the demand curve in response to a large (relative) price increase.

Consumer Response to Large Price Changes

A Theoretical Model

Traditional economic theory takes tastes as given. Similarly, the empirical work based on traditional theory allows for taste changes by assuming that they are either of a once-and-for-all nature or occur in the long run. The concern, however, is generally with "pure" taste changes, i.e., changes in tastes unrelated to the technology of household production. In contrast, the modern theory of consumer behavior, while recognizing pure taste changes, stresses the importance of differentiating two types of "taste-like" shifts in the demand curve. The first is a shift due to a "pure" taste change, i.e., a change in preferences defined over the abstract or produced commodities. The second is a shift due to the introduction of new household production technology through learning on the part of the household.

The modern economic theory of consumer behavior recognizes that households are akin to small factories (Lancaster). They combine capital goods (e.g., stoves), raw materials (e.g., meat), and labor (time spent cooking) to produce commodities (e.g., tasteful and nourishing meals). In general, households are viewed as purchasing goods in the market for use as inputs in the production process within the home. The production process is generally characterized by conventional production functions and the produced commodities are the arguments of conventional utility functions. In short, households are viewed as both producing units and utility maximizers. More specifically, assume that the household possesses a utility function, U, which represents the household's tastes with respect to certain produced commodities, z_i. These produced

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commodities may be a "clean household environment," "nutritious and tasty meals," etc. In symbols, the household's utility function is given by

$$U = U(z), \quad (1)$$

where $z' = (z_1, \ldots, z_n)$.

The production conditions for the household can be expressed by conventional production functions:

$$z = f^i(x^i), \text{ for } i = 1, \ldots, n, \quad (2)$$

where $x^{i\prime} = (x^i_1, \ldots, x^i_m)$ and x^i_j is the amount of the jth good used in the production of the ith commodity. For example, x^i_j might be the amount of water used in the production of the ith commodity, say "clean clothes." In this case, the other inputs might include the amounts of washing machine capacity, electricity, detergent, and household time devoted to washing clothes.

For purposes of exposition, the household's decision process can be decomposed into two stages: a production stage and a consumption stage. In the production stage, the household, given its knowledge of the production process, determines the input combinations that produce a given level of the ith commodity at least cost for given input prices. This minimization problem yields constant output demand functions for the inputs in which the demand depends upon the level of output of the produced commodity and the vector of input prices. These constant output demand functions can then be used to derive the cost functions for producing any given level of the produced commodities.

In the consumption stage, the household determines the levels of the produced (abstract) commodities so as to maximize utility subject to its budget constraint. The budget constraint, in this case, states that the full income of the household must be greater than or equal to the sum of the total costs of producing the abstract commodities.[1] This maximization process yields demand functions for the produced commodities that depend on the prices of all the inputs and full income. Our interest, however, is not with the demands for the produced commodities but rather with the final derived demands for the inputs (purchased commodities) used in producing these abstract commodities. The final derived demand functions follow from combining the production and the consumption stages. By substituting the demand functions for the produced commodities, derived in the consumption stage, into the constant output demand functions for inputs, derived in the production stage, we can obtain the household's derived demands for market goods. The derived demands depend, therefore, on the household's tastes, defined over the produced or abstract commodities, and the existing production technology, as known by the household, as well as prices and income.

[1] Full income is defined as the sum of nonlabor income and the household's wage rate times the total time available.

The demand functions incorporate a standard income effect and two substitution effects. The first substitution effect is comparable to the traditional one and results from the change in the implicit price of the ith commodity (i.e., the marginal cost) brought about by the change in the input price. The second substitution effect results from the change in the least costly way of producing a given output of the produced commodity, for a given technology, when the input price changes.

At any given time, the household does not have complete knowledge of the existing set of production technologies since it may not pay the household to invest sufficient time and money to acquire this information. As a result, changes in the household's knowledge of the existing state of technology will generally be reflected in changes or shifts in the derived demand functions. Large relative price increases, by making it profitable to try to shift the production relations, may well lead the household to become more knowledgeable of the existing state of technology. In short, large relative price increases may shift the derived demand functions.

The essential point is to distinguish taste shifts in the demand curve. One is true taste change represented by a shift in equation (1). The other is a shift, through learning of a new household technology, in equation (2). The true taste change is unaffected by price; the "taste-like" change in household production techniques is a direct result of relative price changes, e.g., large price changes induce search for better methods which in turn cause backward, and perhaps permanent, shifts in the demand function. Finally, the effect is asymmetrical: large price increases lead to the discovery of new techniques which, once known by the household, are retained as new production possibilities despite equivalently large, subsequent price decreases.

Some Illustrations and Evidence

A systematic and thorough test of the above asymmetry hypothesis is beyond the scope of this note. However, we will first illustrate the types of responses predicted and then offer some evidence of substantial (and permanent) shifts in household production functions. Finally, we shall show the problems of estimation and interpretation which result when "taste-like," technological changes in household production are not identified.

As one example, consider the relationship between beef prices and use of recipes for leftovers. Acquiring knowledge of and experience with such recipes can be both time consuming and, on occasion, unpleasant. Given large increases in beef prices, however, additional experimentation with recipes for leftovers becomes worthwhile. Some of the recipes tried will prove useful and, should beef prices subsequently decline, the knowledge of and experience with these recipes will remain. Hence, if leftovers were typically discarded previously, a

permanent reduction in household beef consumption can result from the price increase.

As a second example, consider residential water use for domestic purposes.[2] Elsewhere we have estimated the short-run price elasticity of demand for water (domestic use) by residents as close to unity for large increases in water rates (Hogarty and Mackay). In contrast, the corresponding price elasticity for the large reductions in rates that followed the earlier rate increases is close to zero. Hanke's study of residential water demand contained similar results. One obvious reason for this is that large increases in water rates encourage repair of leaks. Should rates subsequently decline, such maintenance will stop; however, new leaks occur only in the very long run. Another reason is the "trick" of placing a brick in toilets; once placed, the brick will likely remain even if water rates are reduced. In sum, while low rates can make inefficient use of water tolerable (inexpensive), reduced rates offer little incentive to reintroduce inefficiency after it has been eliminated.

For evidence of technological change in households and the resultant asymmetry, consider the data in table 1. These data suggest an immediate and permanent reduction in coffee consumption in response to large price increases. Since the data represent cups per pound of coffee, prices of substitutes can be ignored. Moreover, for example, per capita incomes were certainly higher in 1955 than in 1954. Yet the 25% price increase (in real terms) during 1953–54 induced a 19% increase in cups per pound, while the 15% price reduction in 1954–55 (1957–58) resulted in no change in cups per pound.

Note further that the increase in the extraction rate during 1953–54 was preceded by a 15% increase in cups per pound during 1949–50 (in response to a 42% increase in price in real terms). This suggests that (*a*) taste-like changes need not be a once-and-for-all phenomenon and (*b*) the response will be greater as the initial price level is higher. We also see that small price increases (e.g., 1952–53) have no observable impact.

To comprehend the data in table 1, we must refer to technological changes within the household. Suppose, for illustration, that coffee yields utility characteristics consisting of caffeine, (pleasant) bitterness, and (perhaps) warmth. In that case, the higher price for beans could induce households to be more efficient in extracting characteristics from a given amount of beans. For example, additional brewing time can extract more caffeine; it will also affect the taste (excessive bitterness), but this can be partially offset by use of salt in the brewing process and sugar subsequently. In any event, since longer brewing must involve some change in taste, we have used the term "taste-like" change to describe technological changes within the household.

[2] Domestic use excludes car washing, sprinkling, etc.

Table 1. American Domestic Coffee Consumption per Pound of Ground Coffee and Price per Pound, 1949–58

Year	Cups per Pound of Coffee Brewed at Home	Retail Price (¢/lb.)	
		Nominal	Real[a]
1949	45.9	55.4	55.4
1950	52.6	79.4	78.4
1951	52.3	86.8	77.1
1952	52.9	86.8	75.7
1953	52.8	89.2	79.0
1954	62.7	110.8	98.4
1955	62.7	93.0	83.8
1956	63.9	98.8	88.4
1957	63.9	96.4	83.5
1958	63.9	85.5	71.1

Source: U.S. Federal Trade Commission, appendix table 4. (Data had been provided by Pan American Coffee Bureau.)

[a] Computed by deflating with consumer price index for food (1949 = 100).

Suppose asymmetry exists, as in the time-series data of table 1, but the econometrician is unaware of its presence. In such a case, regression analysis may produce biased estimates of demand elasticities. For example, backward shifts in demand functions, induced by technological changes within the household and not specifically accounted for in the regression equation, can produce a downward bias in the estimate of income elasticity.[3] Hence, given time-series data characterized by large, sudden price increases (e.g., 15% per year), adjustments to data or introduction of an additional independent variable are required to minimize the likelihood of biased estimates.

Conclusions

More than sixty years ago, W. Mitchell concluded that the rate of technological change in production of goods greatly exceeded that in the consumption of goods. The presumed backwardness of households relative to firms may be true today as well. However, we have attempted to show that this backwardness, to the extent it exists, is relative.

[3] Income elasticity estimates for coffee have been provided by Hughes, and Harmston and Hiroyuki. The Hughes study found a negative income elasticity for 1947–66 (versus a positive value for 1920–41) and the Harmston-Hiroyuki study estimated the income elasticity as 0.25 in 1955 and 0.08 in 1965 (p. 385, table 2). Hughes attributed the low income elasticity to competition from superior goods (e.g., liquor) while Harmston-Hiroyuki suggested improvements in soft drinks as the reason for the declining elasticity.

Since liquor is a depressant while coffee is a stimulant and (most) soft drinks are neither, a simpler interpretation is that rapid increases in coffee prices stimulated technological change by both firms and households. Improvements in instant coffee, which required fewer green beans per cup, was the processor's reaction to higher green bean prices. Households responded not only with greater purchases of instant coffee but also probably with longer brewing time.

Household consumption does undergo technological change, particularly when economic incentives are offered.

These taste-like, technological changes can induce a backward shift in demand curves when large price increases occur. If such backward shifts are quasi-permanent, asymmetry will be encountered. Specifically, estimated price elasticities for price increases will exceed those for price decreases. Alternatively, biased estimates of other (e.g., income) elasticities may result. In either case, caution in the estimation, and especially the interpretation, of demand elasticities is necessary whenever large price increases are observed.

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On the Use of Theil's Inequality Coefficients

Raymond M. Leuthold

Authors of papers published in this *Journal* occasionally use Theil's inequality coefficients as measures of the accuracy of a set of predictions generated from some model. One of the first applications was by Hee in 1966, and two recent uses were by Tryfos and by Sahi and Craddock. However, some confusion can arise because there are two different inequality coefficients, one of which can have two alternative interpretations depending upon data definitions. This can result in researchers drawing entirely different conclusions about the predictive powers of models, depending upon which formulation is used to compute the statistic. Further misunderstanding sometimes arises when an inequality coefficient is endowed with statistical powers it does not possess, and more recent criticism has demonstrated that under certain conditions the coefficients can be potentially misleading. It is the purpose of this note to clarify and discuss these issues.[1]

A summary measure of forecasting accuracy by Theil which has gained considerable popularity was proposed in 1958:

$$U_1 = \sqrt{\Sigma(p_t - A_t)^2} \Big/ (\sqrt{\Sigma P_t^2} + \sqrt{\Sigma A_t^2}),$$

with "P_t being the predictions and A_t the corresponding actual outcomes" (1958, p. 32).[2] Many researchers, such as Hee, Meyer and Glauber, Sahi and Craddock, Tryfos, and Tryfos and Tryphonopoulos, have utilized this inequality coefficient, employing actual data. However, two pages later in this same book, Theil states, "All applications of the inequality coefficients in the following chapters will refer to predicted and actual *changes* in the variables" (1958, p. 34, italics added). Herein lies the first source of confusion, since obviously different values of U_1 can be generated depending upon whether actual values are employed or changes in the variables. But, first, what are the advantages and characteristics of the U_1 statistic?

One advantage of the above statistic over some alternative summary measures, regardless of how data are defined, is that it is bounded to the interval 0 and 1. A value of 0 for U_1 indicates perfect prediction, while a value of 1 corresponds to perfect inequality or negative proportionality between the actual and predicted values. A second feature, although not unique to U_1, is that the numerator can be decomposed into its bias component, variance component, and covariance component (Theil 1958, pp. 34–35), allowing for possible evaluation as to the source of the forecast error. No known decomposition has occurred in this *Journal*, although such an evaluation has been done by Meyer and Glauber. Finally, U_1 has the advantage of covering the case where the forecasts are consistently over- or underestimated, that is, it penalizes for a systematic linear bias whereas r^2, for example, would not.[3]

A key shortcoming of U_1 for both actual data and changes is that the measure of the prediction error depends on the predictions themselves, that is, the purpose is to assess P_t, but the assessment is made relative to P_t itself since P_t^2 is in the denominator.

If one uses actual data to compute U_1, calculation is straightforward and, commonly, researchers compare the predictive abilities of various models by simply comparing respective U_1's. However, problems may arise because interpretation of the meaning of the value of the computed statistic remains difficult (Bliemel, p. 445), and the coefficient may not provide a reasonable ranking of models, a point discussed below.

A major problem with using the U_1 statistic when calculated from data defined as actual values is the sensitivity it has to additive transformations. Adding a positive constant to any series of P_t and A_t will reduce its U_1 coefficient but not the correlation coefficient between the set of P's and A's. Consequently, that is why Theil said that his applications "will refer to predicted and actual changes in variables, so that the origin from which the P's and A's are measured is then fixed" (1958, p. 34). Stekler also interpreted the U_1 statistic as being "designed to measure the absolute difference between the predicted change and the actual change" (p. 439). Thus, U_1 as defined by Theil was never designed for actual variate models, and such application is a serious misuse of the inequality coefficient measure of prediction accuracy. Yet, many applications have used observed data instead of changes in the variables. If the predicted change is defined as $\Delta P_t = P_t - A_{t-1}$ and actual change defined as $\Delta A_t = A_t - A_{t-1}$, which are normally the cases, then the numerator remains the same regardless of whether actual data or changes are incorpo-

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[1] Bliemel and Stekler have also reviewed and discussed Theil's inequality coefficients.

[2] A second edition of this book appeared in 1961 with a second printing in 1965, but the discussion concerning this coefficient remained identical with that published in 1958.

[3] Comparing other sources of error and how they affect this and alternative measures is discussed further by Granger and Newbold and by Hirsh and Lovell.

rated.[4] Hence, only the denominator changes, changing the size of the coefficients computed. When actual variates are used, the coefficient is smaller thereby overstating the predictive ability of the models.[5]

The range for U_1 when using changes in variables still remains between 0 and 1, but the interpretation becomes more inconclusive. The lower boundary still refers to an ideal forecast, but $U_1 = 1$ when all $\Delta P_t = 0$, the case of the naive no-change extrapolation model where the forecast for the next period is this period's actual observation. Since this model is often used as a reference point, all other models would predict at least as well as, or more accurately than, the naive no-change model. This creates a very limiting and unreasonable situation and a distinct disadvantage for using U_1.[6]

Finally, further misunderstanding can arise when U_1 is given more statistical powers than it possesses, as in the case of two recent articles by Tryfos and by Tryfos and Tryphonopoulos which appear to be presenting U_1's (defined with actual data) as surrogate r^2's. In the introduction of each of these articles, there are similar sentences referring to the comparison between actual and predicted values as evidence that the estimated functions explain a large proportion of the variation of the dependent variable. Admittedly, the U_t coefficient, r^2, and standard error of estimate may rank alternative models in the same order, but interpretation of the U_1 statistic is vastly different than the usual interpretation given to the coefficient of determination.

In 1966, Theil (1966, p. 28) proposed a modification to his inequality coefficient as follows:

$$U_2 = \sqrt{\Sigma\,(P_t - A_t)^2} \Big/ \sqrt{\Sigma\, A_t^2},$$

where the P's and A's are defined as changes in predictive and actual values, respectively.[7] He states two reasons why one might prefer U_2 over U_1. "First, it is related more directly to the concept of the failure of the forecast. . . . Secondly, the alternative denominator [U_1] depends on the forecasts and it is therefore not true that the coefficient is uniquely determined by the mean square predictive error (given the data on realizations). This is against the idea of a quadratic loss criteria" (1966, p. 28).

The statistic U_2 is bounded by 0, the same as U_1, with perfect forecasts. However, it has no upper bound and takes on a value of 1 when the prediction method is the naive no-change extrapolation. Consequently, U_2, as opposed to U_1, can take on values greater than 1 for models less accurate than no-change extrapolations. (See Leuthold, MacCormick, Schmitz, and Watts for models generating $U_2 \gtreqless 1$.) The numerator of U_2 can be decomposed in the same fashion as was mentioned previously for U_1.

Thus, if one is to select a Theil inequality coefficient as a means for comparing forecasting accuracy among various models, U_2 appears more flexible, more appropriate in a wider range of circumstances, and easier to understand and interpret than U_1, but for some reason U_2 is not as well accepted. One reason may be the lack of an upper bound for U_2, which could disturb some. A second reason may be that U_1 will always imply considerably better predictive ability than U_2, creating a situation for reporting only favorable results. In any event, due to the development of large econometric models, criteria for evaluating predictive accuracy are undergoing closer examination, and the Theil inequality coefficients are being criticized. Two sets of writers, Granger and Newbold, and Hirsh and Lovell, point out that under the specific conditions of when A, actual outcomes, is generated by an autoregressive process or the average change in $A = 0$, U_1 at least may fail to select the optimum predictor as the best possible method to utilize for making predictions.[8]

Also, to make an adequate evaluation of the forecasts, it may be necessary to go beyond the use of Theil's inequality coefficients and incorporate integrated autoregressive-moving average techniques in the examination procedure (Granger and Newbold). No single statistic can capture all the qualities of an estimated model.

The normal usage of the Theil inequality coefficients in this *Journal* has been to compare the results of different estimation procedures for the same model, to compare alternative econometric models, and to compare various results with naive models, but defining precise conditions where U coefficients are appropriate remains a problem. The main difficulty cited here is that the coefficients are often misused, especially in employing actual variates, instead of differences which overstate the degree of forecasting accuracy, and in misinterpreting

[4] If the predicted change is defined as $\Delta P_t = P_t - P_{t-1}$, this present discussion would not hold and U_1 would take on different meanings. However, this subject plus the evaluation of *ex ante* forecasts will not be pursued here.

[5] The decrease in the size of U_1 can be considerable if actual data are incorporated instead of changes in the data, presenting a considerably higher degree of predictive accuracy. In Hee, the U_1 for the consumption of food using actual data was reported as 0.008, compared with a coefficient based on changes of 0.25. The statistic for the consumption of starch increases from the reported 0.12 to 0.19 when changes are employed. In Tryfos, actual and predicted values are obtainable only from a graph, but approximate new U_1's for beef cattle numbers and sheep and lamb numbers based on changes in the data would be about 0.36 instead of the respective reported 0.017 and 0.015, which are based on actual data. Only in extremely rare situations would U_1 computed with actual data exceed that computed with changes in the data.

[6] Stekler proposed an alternative naive model to use as a standard for comparison (p. 440).

[7] U_2 was actually first proposed by Theil in 1955 but went unnoticed in the literature. In 1958, he switched his preference to U_1 which, with the help of Stekler, has gained much attention as the coefficient to use. Here we note him changing back to U_2 as the preferred coefficient.

[8] Jorgenson, Hunter, and Nadiri also point out that the criteria established for decomposing the numerator are inappropriate and misleading.

the coefficients generated. The U_2 coefficient is capable of comparing and ranking alternative models satisfactorily in situations like those cited in this *Journal* and would be recommended by this author as the preferred measure. U_2 is certainly preferred over U_1 when the naive no-change extrapolation model is one of those being compared. However, for detailed evaluation of the forecasts or where suspicion of systematic variation in the data series exists, then more sophisticated techniques will have to be employed.

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Risk Aversion under Profit Maximization

Richard E. Just

Beginning initially with the work of Friedman and Savage and later with the work of Markowitz, and Tobin, risk aversion became a subject of wide interest in economics.[1] The fundamental justification of risk aversion has since been firmly linked with utilitarian economics. The purpose of this paper, however, is to explore an alternative explanation of risk averse behavior for the firm based not on utility maximization but rather on expected profit maximization. The assumptions used throughout the paper characterize production where both price and quantity are stochastic. In contrast to the usual expected utility maximization framework where both price and quantity variation can be important, profit maximizers are sensitive only to quantity variability.[2]

The results may have particularly significant implications for agriculture because yields are highly stochastic at least in agricultural crop production. Implications are that yield variability may be important for supply response whether farmers behave as expected utility maximizers or simply as expected profit maximizers. Thus, an additional explanation is offered for the importance of risk terms in empirical crop supply response models such as those estimated by Behrman, and Just (1974a and 1974b). The results also serve to emphasize the distinction between price risk and production risk in supply response study. If profit maximization is assumed, then all price risk terms can be disregarded in supply response estimation; only production risk must be considered. If maximization of a nonlinear (or mean-variance) utility function is assumed, then perhaps price and production risk must be considered separately since decision makers may be more sensitive to production risk than to price risk.[3]

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[1] Arrow's work has also become important on a more abstract level, but a treatment of his methods is beyond the scope of this paper.

[2] Quantity variability refers to the variability of actual production about planned production.

[3] Our results also have implications for programming models in cases where production is stochastic. In this sense, our results are a special case of the result which indicates that stochastic programming solutions are sensitive to variances when the expected value of the objective function depends on those variances (see Hadley). Although this result is usually interpreted in an expected utility framework, this paper should emphasize the potential importance for expected profit maximization models.

Non-Utilitarian Risk Aversion in the Competitive Firm

The stochasticization of firm theory began in earnest with the work of Mills, and Oi which introduced price uncertainty under perfect competition. In a number of recent papers (see Sandmo, and Leland, as well as their references), the problem of stochastic price has been reconsidered and the more general problem of stochastic demand has been introduced. With stochastic demand, the firm is assumed to set either price or quantity with the other becoming stochastic. But in either case, the firm is assumed to control its production nonstochastically whether it is preset or adjusted to meet stochastic demand levels. In none of these papers is risk found to play an important role in the case of a linear utility function (profit maximization). It is the purpose of this paper to consider an additional generalization of stochastic firm theory where production is only controlled stochastically but where at least part of the production costs depend on the resulting stochastic production. This generalization is made in the cases of both competition and monopoly. Finally a comparison of these results with utility maximization is made.

Initially we consider a single-product competitive firm and a product price distribution with mean μ_p. Where planned production is q_0, actual production q is assumed to vary stochastically about q_0 with variance $\sigma(q_0)$ explicitly depending on planned production. Marginal cost is assumed to depend on the actual stochastic production as well as the planned production.[4] This compares to an agricultural cropping situation where planting costs depend on planned production, but (because of stochastic yields) harvesting, hauling, and storage costs depend on actual production. It is the dependence of costs on actual production which gives rise to the results in this paper.

For ease of derivation, marginal cost is assumed to be separable with respect to actual and planned production and is denoted by

$$(1) \qquad C(q; q_0) = C_p(q_0) + C_a(q),$$

where $C_p(q_0)$ and $C_a(q)$ are the marginal costs associated with planned and actual production, re-

[4] To avoid specification and manipulation of a production function, only the marginal cost curves (which assume a least cost mix of inputs) are defined explicitly. Assuming nonstochastic input prices, the relationship of cost curves with the production function would be exactly as in elementary firm theory.

spectively, and $C_p(q_0)$, $C'_p(q_0)$, $C_a(q)$, $C'_a(q) > 0$. For expository purposes, $C_a(q)$ is approximated by a second-order Taylor series expansion about the mean q_0,

$$C_a(q) = C_a(q_0) + C'_a(q_0)(q - q_0) + \frac{1}{2} C''_a(q_0)(q - q_0)^2 = \alpha + \beta q + \gamma q^2,$$

where $\alpha = C_a(q_0) - q_0 C'_a(q_0) + \frac{1}{2} q_0^2 C''_a(q_0)$, $\beta = C'_a(q_0) - q_0 C''_a(q_0)$, and $\gamma = \frac{1}{2} C''_a(q_0)$. Where price is represented by p, the firm's profit is

$$\pi = pq - \int_0^{q_0} C_p(x)\,dx - \int_0^{q} C_a(x)\,dx = pq - \int_0^{q_0} C_p(x)\,dx - \alpha q - \frac{1}{2}\beta q^2 - \frac{1}{3}\gamma q^3.$$

Since a competitive firm's production is too small to influence price, we consider p and q stochastically independent.[5] Hence, expected profit is

$$E(\pi) = \mu_p q_0 - \int_0^{q_0} C_p(x)\,dx - \int_0^{q_0} C_a(x)\,dx - \frac{1}{2}\beta\sigma(q_0) - \frac{1}{3}\gamma\eta_q - \gamma q_0 \sigma(q_0),$$

where η_q is the skewness parameter of the q distribution.[6] Assuming skewness does not vary with q_0, the first-order condition for expected profit maximization[7] is

$$(2)\quad \mu_p = C(q_0; q_0) + \left(\frac{1}{2}\beta + \gamma q_0\right)\sigma'(q_0) + \gamma\sigma(q_0) = C(q_0; q_0) + \frac{1}{2} C'_a(q_0)\,\sigma'(q_0) + \frac{1}{2} C''_a(q_0)\,\sigma(q_0).$$

The condition in equation (2) can have several different implications depending on the derivatives of $C_a(\cdot)$ and $\sigma(\cdot)$. Assuming marginal cost is increasing, $C'_a(q) = \beta + 2\gamma q > 0$, and upward bending, $C''_a(q) = 2\gamma > 0$, and the variance in production is nondecreasing in planned production, $\sigma'(q_0) \geq 0$, the condition in equation (2) implies that production will take place where marginal cost at planned production, $C(q_0; q_0)$, is less than expected price. In other words, the quantity produced will be less than that quantity which equates marginal cost and expected price because $\frac{1}{2} C'_a(q_0)\,\sigma'(q_0) + \frac{1}{2} C''_a(q_0)\,\sigma(q_0) > 0$. Furthermore, the deviation from the classical "price equals marginal cost" production point is smaller when the function $\sigma(q_0)$ is replaced with an alternative variance function $\sigma^*(q_0)$ indicative of some other production technology if $\sigma^*(q) < \sigma(q)$ at all q. In other words, for reduced variation in production, expected profit-maximizing entrepreneurs will increase planned output q_0, *ceteris paribus*. But this is the same kind of behavior we would expect from an expected utility-maximizing entrepreneur with risk-averse utility.

Similar conclusions also hold under certain conditions when marginal cost is linear. Suppose the random deviation of actual production from planned production is defined by

$$(3)\qquad q - q_0 = [f(q_0)]^{\frac{1}{2}}\epsilon,$$

where ϵ is stochastic with mean zero and fixed variance ω, and $f(\cdot)$ is some positive continuous monotonic function indicative of the effect of planned production on production variability. For example, in a simplified agricultural situation where acreage is the only input, ϵ may be defined as the excess of actual per acre yields over expected yields. Hence, the function $[f(q_0)]^{\frac{1}{2}}$ would represent acreage, i.e., planned production q_0 divided by expected yield. If per acre use of other inputs is variable, then $f(q_0)$ would be a more complicated function of q_0. Using the definition in equation (3) implies $\sigma(q_0) = \omega f(q_0)$ and, hence, the condition in equation (2) becomes ($\gamma = 0$, under linearity)

$$(4)\qquad \mu_p = C(q_0; q_0) + \frac{1}{2}\beta\omega f'(q_0).$$

The effects of reducing risk through, say, some production-stabilizing technology can be examined using the parameter ω. Assuming increasing marginal cost, $\beta > 0$, and increasing production variance in planned production, $f'(q_0) > 0$, the second term on the right-hand side of equation (4) is positive and is increasing in ω. Hence, (for increasing marginal cost) the reduction in planned production from the point where expected price equals marginal cost is increasing in ω. In other words, if ω is reduced by introducing some production-stabilizing technology, profit-maximizing entrepreneurs will increase output and, thus, behave as risk averters.[8]

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[5] Admittedly, this assumption may be oversimplifying to some extent. Stochastic weather conditions, etc., may cause some correlation between all firm outputs which will lead to some correlation with price. If price and quantity are correlated, then the analysis of this section would be changed by replacing $E(pq)$ by $\mathrm{cov}(p, q) + \mu_p q_0$ instead of $\mu_p q_0$. Results would be unchanged except that the effects of $\sigma'(q_0)$ could be reduced somewhat if $\mathrm{cov}(p, q)$ depends directly on q_0 or equivalently on $\sigma(q_0)$. For example, the reader may note the reduced effects of $\sigma'(q_0)$ in the following section where price and quantity are perfectly correlated.

[6] Recall the statistical identity

$$E(q^3) = \eta_q + 3q_0\,\sigma(q_0) + q_0^3.$$

[7] The condition in equation (2) departs not only from the "price equals marginal cost" rule but also from the more general "expected price equals expected marginal cost" rule because $\sigma(q_0)$ depends on q_0. We could rewrite equation (2) as

$$E(p) = E[C(q; q_0)] + \left(\frac{1}{2}\beta + \gamma q_0\right)\sigma'(q_0).$$

[8] The words "behave as" must be emphasized here. If planned output is increased when risk increases, we say he behaves as a risk lover; if planned output is reduced when risk increases, we say he behaves as a risk averter. We do not discuss the entrepreneur's actual preferences for risk. One can verify that the firm

In general, the profit-maximizing entrepreneur will behave as a risk lover when opposite conditions hold. If production variation does not depend on planned production, $\sigma'(q_0) = 0$, producers will reduce output in response to a reduction in risk when marginal cost is downward bending, $C''_a(q_0) < 0$. If marginal cost is linear (and increasing), producers will reduce output in response to a reduction in risk when production variation is decreasing in planned production, $\sigma'(q_0) < 0$. Obviously, producers also behave as risk lovers if both the above conditions hold.

Although we could additionally investigate the effects of risk on input use, no additional information is forthcoming. If entrepreneurs produce planned output in a least-cost manner, planned input use increases in response to a reduction in risk when the conditions for risk averse behavior (above) are satisfied since q_0 increases. The opposite would hold when conditions imply risk-loving behavior.

Non-Utilitarian Risk Aversion under Monopoly

Only the case where stochastic variation in output has no influence on price has been considered up to this point. In this section, price depends perfectly on the stochastic production. The firm is assumed to perceive a downward sloping demand curve approximated by a second-order Taylor series expansion about q_0,

$$(5) \qquad p = a + bq + cq^2.$$

Results indicate that expected profit-maximizing monopolists may be more or less risk averse than similar competitive firms depending on demand conditions. Risk implications are reversed if curvature of the marginal revenue curve is more extreme than for the marginal cost curve.

Expected profits for a monopolist with the marginal cost curve in equation (1) and demand curve in equation (5) are

$$E(\pi) = aq_0 + bq_0^2 + cq_0^3 + b\sigma(q_0) + c\eta_q + 3cq_0\,\sigma(q_0) - \int_0^{q_0} C_p(x)\,dx - \int_0^{q_0} C_a(x)\,dx - \frac{1}{2}\beta\sigma(q_0) - \frac{1}{3}\gamma\eta_q - \gamma q_0\,\sigma(q_0).$$

When η_q (skewness) does not depend on q_0, first-order conditions for expected profit maximization imply

$$(6) \quad R(q_0) = C(q_0; q_0) + \frac{1}{2}[C'_a(q_0) - R'(q_0)]\,\sigma'(q_0) + \frac{1}{2}[C''_a(q_0) - R''(q_0)]\,\sigma(q_0) = C(q_0; q_0) + \left[\frac{1}{2}\beta + \gamma q_0 - b - 3cq_0\right]\sigma'(q_0) + [\gamma - 3c]\,\sigma(q_0),$$

where $R(q_0)$ represents marginal revenue at q_0.

First, consider the alternative where demand and marginal cost are linear but where production variability increases with planned production. The relationship in equation (6) continues to hold, but the third right-hand-side term becomes zero. For increasing marginal cost and a negatively sloped demand curve, $C'_a(q_0) - R'(q_0)$ is a positive constant, say β^*, greater than β. Substituting equation (3), we find that marginal revenue exceeds marginal cost by $\frac{1}{2}\beta^*\omega f'(q_0)$. Hence, the monopolist acts as a risk averter when production variability increases with planned production, $f'(q_0) > 0$, since smaller ω implies a smaller excess of marginal revenue over marginal cost. Furthermore, the monopolist acts more risk averse than a competitor under similar conditions since $\beta^* > \beta$. If production variability is decreasing in planned production, then the monopolist contracts production in response to a reduction in ω since the excess of marginal revenue over marginal cost is negative. In this case, the monopolist acts as a risk lover to a greater degree than a competitor under similar conditions.

Secondly, consider the case where variability of production does not depend on planned production, $\sigma'(q_0) = 0$. If marginal cost and demand are both upward bending (but marginal cost is positively sloped and demand is negatively sloped), the condition in equation (6) indicates that marginal revenue should be greater (less) than marginal cost only when the curvature in marginal cost, 2γ, is greater (less) than the curvature in marginal revenue, $6c$. Since γ and c are constant, the deviation of q_0 from the quantity where $R(q) = C(q_0; q_0)$ is smaller for smaller $\sigma(q_0)$. Hence, for $\gamma > 3c$ the monopolist acts risk averse; for $\gamma < 3c$ the monopolist acts as a risk lover. In the case of risk aversion, the monopolist acts risk averse to a smaller degree than a competitive firm (the deviation of marginal revenue and marginal cost is smaller), since the coefficient of $\sigma(q_0)$ is $\gamma - 3c$ for the monopolist in equation (6) but simply γ for the competitor in equation (2).[9]

Examining alternative cases where $\sigma'(q_0) = 0$ we find the monopolist acts more risk averse (loving)

will have lower expected profits with greater production variability regardless of the conditions discussed in this paper so long as marginal cost is increasing.

[9] Actually the difference in the degree of risk averse behavior in terms of quantities produced is even greater than indicated by the coefficient of $\sigma(q)$, indicative of the difference in $R(q_0)$ and $C(q_0; q_0)$. This is true since marginal revenue is decreasing for the monopolist but constant for the competitor. Hence, for a given positive difference $R(q_0) - C(q_0; q_0)$, the competitor will produce less than the monopolist, *ceteris paribus*. Unfortunately, we cannot apply the ordinary Pratt measure of risk averseness here since it depends on the utility function. The Pratt measure would indicate no risk aversion in both cases, when, in fact, planned output increases in response to a reduction in risk, i.e., reduction in $\sigma(q_0)$ at all q.

than the competitor when marginal cost is upward (downward) bending and demand is downward (upward) bending. If both marginal cost and demand are downward bending, then risk behavior depends on the relationship of the curvatures. A monopolist would act less risk loving than the competitor and would become risk averse when $\gamma < 3c$.

Although we do not pursue the more general case, the monopolist's risk preferences can also be easily deduced for nonlinearity when $\sigma'(q_0) \neq 0$.

The Two Product Case: A Comparison with Utility Maximization

In this section, the cases of expected profit and expected utility maximization are compared very briefly in the stochastic production case. Where price is nonstochastic, both behavioral assumptions imply that decisions depend on risk but decisions are more sensitive to risk in the case of a risk averse mean-variance utility function. When both price and production are stochastic, an expected profit maximizer is insensitive to price risk but an expected utility maximizer can be sensitive to both price and production risk. Results also indicate that correlated production can lead to diversification under either behavioral assumption, but correlated prices lead to diversification only in the case of utility maximization.

We begin by solving the general utility maximization problem with both stochastic production and price. The desired results can then be obtained by examining first-order conditions for specific values of some of the parameters. For purposes of simplicity, marginal cost is assumed to depend completely on actual production.[10] Also, total cost is approximated by the quadratic function

$$C_T(q_1, q_2) = \alpha_1 q_1 + \alpha_2 q_2 + \beta_1 q_1^2 + \beta_2 q_2^2 + 2\theta q_1 q_2,$$

where the two (actual) product quantities are denoted by q_1 and q_2 and α_i, β_i, and θ are fixed parameters. For respective prices p_1 and p_2, profits are

$$\pi = p_1 q_1 + p_2 q_2 - C_T(q_1, q_2).$$

Again assuming competition or that a firm's production is too small to influence price, the stochastic variation in production at the firm level is assumed to be independent of prices. Moments of the stochastic distributions are denoted as follows: $q_i^0 = E(q_i)$, $\mu_i = E(p_i)$, $\sigma_{ij}^q = E[(q_i - q_i^0)(q_j - q_j^0)]$, and $\sigma_{ij}^p = E[(p_i - \mu_i)(p_j - \mu_j)]$. Finally, the random deviation of actual production from planned production is again defined to depend on planned production as in equation (3),

$$q_i - q_i^0 = f_i(q_i^0)\,\epsilon_i, \quad i = 1, 2,$$

where ϵ_i is stochastic, $E(\epsilon_i) = 0$, $E(\epsilon_i\epsilon_j) = \omega_{ij}$ and ω_{ij} is fixed. Hence,

$$(7) \qquad \sigma_{ij}^q = f_i(q_i^0) f_j(q_j^0)\,\omega_{ij},$$

so that σ_{ij}^q is increasing in both q_i^0 and q_j^0 when $f_i(q_i^0)$ and $f_j(q_j^0)$ are increasing in q_i^0 and q_j^0, respectively.

Expected profits are

$$E(\pi) = \mu_1 q_1^0 + \mu_2 q_2^0 - C_T(q_1^0, q_2^0) - \beta_1\sigma_{11}^q - \beta_2\sigma_{22}^q - 2\theta\sigma_{12}^q.$$

The variance of profits may be represented[11] as

$$\sigma_\pi = \psi_1 + \psi_2 + \psi_3,$$

where

$$\psi_1 = (q_1^0)^2\,\sigma_{11}^p + (q_2^0)^2\,\sigma_{22}^p + 2q_1^0 q_2^0\,\sigma_{12}^p,$$

$$(8) \quad \psi_2 = \mu_1^2\sigma_{11}^q + \mu_2^2\sigma_{22}^q + 2\mu_1\mu_2\sigma_{12}^q + \mathrm{var}[C_T(q_1, q_2)],$$

and

$$\psi_3 = \sigma_{11}^q\sigma_{11}^p + \sigma_{22}^q\sigma_{22}^p + 2\sigma_{12}^q\sigma_{12}^p - 2\,\mathrm{cov}[p_1q_1 + p_2q_2, C_T(q_1, q_2)].$$

Here, note that $\psi_1 \equiv \psi_3 \equiv 0$ if prices are nonstochastic and $\psi_2 \equiv \psi_3 \equiv 0$ if production is nonstochastic. Assuming that the covariance matrix for prices $\{\sigma_{ij}^p\}$ is positive definite, ψ_1 must be increasing in both q_1^0 and q_2^0. It can also be shown that $\psi_2 + \psi_3$ must be increasing in both q_1^0 and q_2^0 if the covariance matrix $\{\omega_{ij}\}$ is positive definite and $f_i(q_i^0)$ is increasing in q_i^0, $i = 1, 2$.

Using a general mean-variance expected utility function,

$$U(q_1^0, q_2^0) = E(\pi) - \phi\sigma_\pi,$$

with fixed parameter ϕ, first-order maximization conditions indicate

$$(9) \quad \mu_i = C_i(q_i^0) + \beta_i \frac{d\sigma_{ii}^q}{dq_i^0} + 2\theta \frac{\partial\sigma_{ij}^q}{\partial q_i^0} + \phi\left[\frac{\partial\psi_1}{\partial q_i^0} + \frac{\partial\psi_2}{\partial q_i^0} + \frac{\partial\psi_3}{\partial q_i^0}\right], j = 3 - i; i = 1, 2,$$

where $C_i(q_i)$ represents marginal cost for q_i. In comparison, expected profit maximization would imply first-order conditions as in equation (9), except with $\phi = 0$.

The cases of nonstochastic price can be considered by setting all σ_{ij}^p equal to zero in which case $\psi_1 \equiv \psi_3 \equiv 0$ and hence, $\partial\psi_1/\partial q_i^0 = \partial\psi_3/\partial q_i^0 = 0$. With utility maximization, the last term in equation (9) would be replaced by $\phi\partial\psi_2/\partial q_i^0$. With profit maximization, the last term in equation (9) would be dropped. The conditions would differ only by the $\phi\partial\psi_2/\partial q_i^0$ terms which would be of the same

[10] Omission of marginal cost associated with planned production results in no loss of generality. As in previous sections, its inclusion is not responsible for modifying the usual "price equals marginal cost" rule.

[11] Here we use the fact that

$$V(XY) = V(X)\,V(Y) + V(X)\,[E(Y)]^2 + V(Y)\,[E(X)]^2,$$

when X and Y are independent random variables.

sign as ϕ under the positive definiteness and increasing production-variance assumptions made above (so long as marginal cost is increasing in q_i^0). But using equation (7), it can be shown that both ψ_2 and $\partial\psi_2/\partial q_i^0$ are increasing in ω_{ii}. Since the excess of (expected) price μ_i over expected marginal cost $C_i(q_i^0)$ is inversely related to planned production, the effects of a change in risk associated with a change in ω_{ii} can be determined in each case. If risk is reduced by reducing ω_{ii}, then $\beta_i \frac{d\sigma_{ii}^q}{dq_i^0} + 2\theta \frac{\partial\sigma_{ij}^q}{\partial q_i^0}$ would be reduced by the same amount in both first-order conditions. However, the utility maximizer's conditions would also change due to the $\phi\partial\psi_2/\partial q_i^0$ term. If $\phi > 0$ (risk averse utility function), then $\phi\partial\psi_2/\partial q_i^0$ would decrease and, hence, the utility maximizer would increase output more in response to a reduction in risk than a profit maximizer. If $\phi < 0$, then the utility maximizer would increase output less and possibly even reduce output. Comparing with the ordinary case of a risk averse mean-variance utility function ($\phi > 0$), we conclude that the utility maximizer acts more risk averse than a profit maximizer, but both kinds of producers respond to changes in production risk. Furthermore, if we examine the effects of a change in ω_{12} on first-order conditions, it also becomes apparent that an increase in covariance of production can lead to more diversification (depending on f_1 and f_2) for both kinds of producers.

If only price is stochastic, then $\partial\psi_1/\partial q_i^0$ must be considered. In the simple case where production is nonstochastic, the first-order condition for profit maximization would be $\mu_i = C_i(q_i^0)$, $i = 1, 2$, since $\sigma_{ii}^q = \sigma_{ij}^q \equiv 0$ and $\phi = 0$. Hence, in the usual firm theory case, the profit maximizer would be insensitive to changes in price risk. First-order conditions for the utility maximizer would be $\mu_i = C_i(q_i^0) + \phi\partial\psi_1/\partial q_i^0$. Since the term $\phi\partial\psi_1/\partial q_i^0$ depends on all σ_{ij}^p, the utility maximizer would be sensitive to changes in both the variance and covariance of prices. As in the usual case of expected utility maximization, $\phi > 0$ would imply a reduction in q_i^0 in response to an increase in σ_{ii}^p (a risk averse response). If $\phi < 0$, then q_i^0 would increase in response to an increase in σ_{ii}^p.

If both price and production are stochastic, then conclusions are essentially the combination of the conclusions in the above special cases. This is true since the first three terms of ψ_3 in equation (8) only serve to magnify the effects of price and production variances and covariances in ψ_1 and ψ_2 and because the last term in equation (8) can never cancel out the variances of returns and costs in ψ_1, ψ_2 and the first three terms of ψ_3 unless returns and costs are perfectly positively correlated. Hence, we conclude that an expected profit maximizer responds only to changes in production risk but not to changes in price risk. But an expected utility maximizer will respond to both so long as $\phi \neq 0$. In the general case of a risk averse utility function ($\phi > 0$), the utility maximizer would be more responsive to production risk than a profit maximizer. Although price risk could affect diversification only for a utility maximizer, production risk can possibly affect diversification under either behavioral hypothesis.

Conclusions

The implications of these results are that some care must be taken in empirical analysis of firm behavior in order to discern between profit maximization and maximization of some nonlinear (mean-variance) utility function. To verify reaction to changing risk is not sufficient to refute the profit maximization hypothesis. The results of this paper suggest that one must differentiate between the condition in equation (9) with $\phi = 0$ and $\phi \neq 0$ where, of course, all other parameters are unknown. One possibility would be to show a direct dependence of decisions on price variability since price risk does not enter equation (9) under profit maximization (when $\phi = 0$). Associated statistical tests could be performed using risk models such as the one used in a recent study by Just (1974a, 1974b) except separate risk terms would be included for both price and quantity. But this procedure also may not be conclusive because of multicollinearity problems. Since price is sometimes highly correlated with production, it often may be impossible to show that production variability is not the underlying reason behind empirical significance of price-risk models. The same would also be true for price variability with production-risk models. Statistical results may be inconclusive unless price risk proves significant when production risk is also considered. Finally, when statistical difficulties prevent conclusive results, it may be sufficient to additionally investigate existence of the underlying conditions which give rise to production-risk sensitivity for profit maximizers. If such conditions do not exist, then any reaction to a change in risk would be sufficient to differentiate the two cases discussed in this paper.[12] The results of this paper indicate that production-risk sensitivity under profit maximization depends critically on the nonlinearity of marginal cost or on the dependence of production variability on planned production. Both conditions, however, seem to be of some importance in agriculture. Particularly in the case of the latter, production variance in crop production (the square of acreage times yield variance) must be increasing in acreage. Hence, if acreage is increased when planned production is increased, then production

[12] In a more general possibly dynamic framework, some more possibilities would exist. For example, the plans of an expected utility maximizer may be sensitive to changes in liquid wealth while those of an expected utility maximizer are not. An analysis of this and related problems, however, is beyond the scope of this paper.

variance must be increasing in planned production (unless yield variance decreases with acreage). Supposing that marginal cost is not downward bending, our results lead to some suspicion that yield-stabilizing as well as yield-increasing technology can be important in expanding agricultural production regardless of whether profit maximization predominates. The results thus emphasize the importance of considering risk in agricultural supply response models. It seems unlikely that agricultural supply response studies can correctly ignore changing production risk even if producers are profit maximizers.

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A Mathematical Model of a Village Cooperative Based on the Decomposition Principle of Linear Programming

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The efforts made by economists to construct a mathematical model of cooperative organization systems have added a great deal to the understanding of such systems and have helped solve some of their problems. A major part of the research on this subject has been described in the *Journal of Farm Economics,* and, among others, we should mention the studies of Robotka, Clark, Phillips, Savage, Aresvic, Trifon, Helmberger and Hoos, and Hardie. Eschenburg attempts to summarize today's state of knowledge.

Most of the works that have attempted to present a complete mathematical model of the cooperative systems have utilized the idea of an internal market. In one form of this idea, the members of a cooperative society supply products which are in demand by the cooperative society (a marketing cooperative). In another form, the cooperative society supplies those production services that are in demand by its members. The latter version of an internal market used in Eschenburg's model (chap. 2) is adopted in this paper.

Under certain assumptions to be specified later, the Eschenburg version of the internal market permits the formulation of a more general model which can incorporate marketing as one of the productive services supplied. This model uses linearity assumptions for generalizing to any number of different services supplied by the cooperative and to any number of different products produced by member firms. The generalization process is similar to the way in which Hardie tried to generalize the Helmberger and Hoos model, but the result is a linear model which differs from Hardie's owing to the different assumptions made.

The model presented here is designed to describe a type of farmers' cooperative which functions in the typical noncollective Israeli village or "moshav" (see Viteles). Such a cooperative serves all of the thirty to eighty farmers in one village, most of whom possess equal quantities of basic production factors (land and water for irrigation), providing them whatever they require for operating their farms (e.g., raw materials and other farm supplies, marketing products, various types of credit, farm machinery on lease, and help with their accounts).

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This model attempts to describe the behavior of the entire village production system, i.e., that of the members as well as that of the cooperative society's management. Members in this case are farms and their behavior is assumed to be consistent with neoclassical theory of the firm. As to management, there are several different ways in which to manage a cooperative (see Eschenburg), and the model is therefore limited by the assumptions to be made in this respect.

The theory of linear programming and the decomposition principle (Dantzig and Wolfe) will be used to present the internal market and to clarify the problems involved in the relations between the cooperative society and its members.

Assumptions

(*a*) A producers' cooperative organization is a group of firms which decides upon joint utilization of jointly owned resources. Management of the joint effort is carried out by forming an additional firm, the cooperative society, which is owned by the member firms. Four principles characterize such a cooperative (mostly following Robotka): joint ownership by the members of certain resources; management of the cooperative society by the members, retaining independent decision making in their own firms; exclusive supplying of the members with certain production services by the cooperative society and obligatory patronizing of these cooperative services by its members; and transfer of any surplus or deficit net returns by the cooperative society to its members.

(*b*) The member firms consider the services supplied by the cooperative society as part of their production process. These services may include procurement of raw materials, piecework farming, processing, packing, marketing, financing, etc.

(*c*) The cooperative's jointly owned resources limit its short-run capacity to supply services to members. The operation of cooperative services presumably requires the existence of certain fixed assets, such as buildings and machinery, limited in the short run. Even services that do not require such assets will in any event need working capital, and we assume that the availability of such capital is also limited in the short run. In other words, there is a short-term limitation on the operation of the cooperative, determined by the quantity of

available capital. Supply of services by the cooperative therefore entails utilizing some of its limited resources. Each member, utilizing his own fixed resources, also utilizes these cooperative resources.

(*d*) The cooperative faces fixed prices in all outside markets in which it buys or sells. This assumption is required in order to describe a marketing and procurement cooperative with a single linear model.

(*e*) The behavior of member firms is guided by the aim of maximizing their current surplus of income over costs incurred, costs which include payments for cooperative services. Firms are free to utilize any of the available facilities and resources owned by the cooperative. The only parameter determining such use of resources is the prices currently charged for them by the cooperative.

(*f*) The aim of the cooperative society's management is to maximize the aggregate surplus left to the firms (the Helmberger and Hoos assumption of maximizing the "cooperative surplus"). Given the variable costs incurred by members, which may also vary according to the different utilization of the cooperative resources, we assume that the surplus to be maximized is this "cooperative surplus" less aggregate variable costs incurred by firms, i.e., the aggregate rent accruing to the fixed resources of both firms and cooperative—in fact, to the fixed resources of the entire system.

(*g*) No decision can be made by the cooperative society which affects its members to the extent that they will choose to leave. This implies a constraint on the behavior of the cooperative society. A minimum surplus of income should be maintained for each member. This assumption is essential to the functioning of the cooperative, in view of its objective of maximizing the aggregate surplus of the members.

(*h*) Finally, the model presents a linear programming problem and the usual assumptions of linear programs (Dantzig) are employed.

The Linear Model

The model comprises a set of constraints for each firm, a set of constraints for the cooperative society, an objective function for each firm as described in assumption (*e*), and an objective function for the cooperative society as described in assumption (*f*). A set of linear programming problems is constructed.

Each firm, ($i = 1, \ldots, M$), has a set of constraints,

$$(1) \qquad A_i X^i = b^i,$$

where A_i is the matrix whose elements indicate the amount of limited resources of firm i required to operate one unit of each possible activity (the activities are different farm enterprises and include slack activities), X^i is the vector of activities operated by the firm (each activity is measured by units of equal scale), and b^i is the vector of available fixed resources owned by the firm.

The cooperative society also has constraints on the amounts of productive services it can supply to member firms. These are represented by

$$(2) \qquad IX^o + \sum_{i=1}^{M} A_i^o X^i = b^o,$$

where A_i^o is the matrix of firm's demand for the cooperative society's services per unit of firm activity, comprising part of the technological matrix $\begin{bmatrix} A_i^o \\ A_i \end{bmatrix}$ of the firm, X^o is the vector of slack variables measuring the amount left idle out of each productive cooperative society resource, and $b^o = (b_1^o, \ldots, b_N^o)$ is the vector of available fixed resources of the cooperative society.

Two kinds of problems should be solved in the cooperative system. One refers to member firms and the other to the cooperative society. The problem facing firm i can be defined as follows:

$$(3) \qquad \max_{X^i} Z_i = (r^i - fA_i^o) X^i,$$

subject to

$$(4) \qquad A_i X^i = b^i; X^i \geq 0,$$

where r^i is the vector of the surplus retained by the firm i from each unit of activity after deduction of the variable costs, both of the firm and of the cooperative society for supplying services to these units. Let p_1 be the output (revenue) of one unit of activity 1 of firm i, C_1^o the variable cost of the cooperative society of supplying the services required by the unit, and C_1 the remaining variable costs for that activity unit being met directly by the firm. Then the surplus r_1 of the unit of activity is

$$r_1 = p_1 - C_1^o - C_1,$$

and the vector of surplus of the firm is $r^i = (r_1, \ldots, r_t)$ for t possible activities of the firm. The variable costs $(C_1^o, \ldots, C_t^o)$ of the cooperative society are charged to the members per unit of service used; r^i is therefore a vector known to each of the firms.

In addition to the variable costs C^o, the cooperative society has total fixed costs, F, which are the overhead expenses composed of three parts: (*a*) depreciation of the society's assets, (*b*) interest on the society's liabilities, and (*c*) overhead management costs. These costs are charged to the accounts of different services, in the case of (*a*) and (*b*) in proportion to the amount of capital earmarked for them and in the case of (*c*) in proportion to their part in the total financial turnover of the cooperative society. This accounting system, which is the accepted procedure, is based on the distinction between variable and fixed costs.

These costs, too, are assumed to be charged to member firms in proportion to the quantity of ser-

vices (or cooperative resources) used, i.e., a vector of prices $f = (f_1, \ldots, f_N)$ is determined for N cooperative services where f_K is the price charged for a unit of service (resource) K. Vector f must be determined in advance of the process described by the model and can be amended by later decisions.

There is no alternative way of pricing variable costs which, by definition, must be charged as direct expenses to each unit of service supplied. Pricing of fixed costs, however, is part of the cooperative society's management policy. The vector of prices f is the main parameter for decision making whereby the cooperative can influence the behavior of member firms. The pricing procedure described above is equivalent to charging the average fixed cost per unit of service. Trifon, Eschenburg, and others have shown that cooperative pricing can be done according to average costs, marginal costs, or some intermediate system, each technique entailing its own particular problems.

Defining r as the vector of output minus variable costs and assuming f the vector of prices for cooperative services additional to the variable costs, the remaining surplus of firm i which should be maximized is therefore

$$r^i X^i - f A_i^o X^i = (r^i - f A_i^o) X^i = Z_i. \tag{5}$$

The definition of the objective function is thus based on a separation of the cooperative society's fixed and variable costs.

The problem faced by the cooperative society can be defined as follows:

$$\max_{X^i} Z = \sum_{i=1}^{M} r^i X^i. \tag{6}$$

The constraints are

$$I X^o + \sum_{i=1}^{M} A_i^o X^i = b^o, \tag{7}$$

$$(r^i - f A_i^o) X^i \geq q \quad (i = 1, \ldots, M);\ q > 0, \tag{8}$$

and

$$A_i X^i = b^i \ (i = 1, \ldots, M);\ X^i \geq 0;\ X^o \geq 0. \tag{9}$$

Maximizing the objective function, equation (6), is equivalent to maximizing the sum of the objective functions of the member firms, equation (3), which equals

$$\sum_{i=1}^{M} Z_i = \sum_{i=1}^{M} r^i X^i - \sum_{i=1}^{M} f A_i^o X^i. \tag{10}$$

The last term, $\Sigma f A_i^o X^i$, must equal either the fixed cost F or a fixed proportion of F; it is therefore a fixed quantity and can be left out of the objective function.[1]

The constraint given in equation (8) means that the surplus of each firm cannot fall below a certain positive value, q. This can be inferred from the assumption in (g) above. The value of q is determined by a decision taken by the cooperative. The constraint may not be binding if q is set small enough in comparison with the cooperative's resources, but it assures that productive activities of each member will appear in the optimal solution.

Decomposition of the Cooperative Problem

The program, equations (6), (7), (8), and (9), of the cooperative society is decomposable into a master program, equations (6), (7), (8), and M subprograms, equation (9).

Dantzig has shown (pp. 462–65) in the analogous case of the multiple plant firm with decentralized management that the decomposition algorithm can be taken as a model of a decision-making process. By the same token, the decision-making process in the cooperative system is represented by the model as an interaction of decisions made by the cooperative society and its members.

Let X^{ij} ($j = 1, \ldots, P_i$) be P_i feasible solutions to the problem, equations (3) and (4), of firm i. These are farming programs being applied by the firm or recommended to it. An equivalent formulation of the cooperative society's problem constituting the master program will be the following, with different independent variables, λ, that define convex combinations of these feasible programs:

$$\max_{\lambda_{ij}} Z = \sum_{i=1}^{M} \sum_{j=1}^{P_i} \lambda_{ij} r^i X^{ij}, \tag{11}$$

$$\sum_{i=1}^{M} \sum_{j=1}^{P_i} \lambda_{ij} A_i^o X^{ij} \leq b^o, \tag{12}$$

$$\sum_{j=1}^{P_i} (r^i - f A_i^o) X^{ij} \lambda_{ij} \geq q \tag{13}$$

$$(i = 1, \ldots, M),$$

and

$$\sum_{j=1}^{P_i} \lambda_{ij} = 1 \ (i = 1, \ldots, M); \tag{14}$$

$$\lambda_{ij} \geq 0 \ (i = 1, \ldots, M; j = 1, \ldots, P_i).$$

The constraint, equation (14), ensures the feasibility of the solution to the firms' problems, equations (3) and (4).

Simplex multipliers Π will be found in each stage of the algorithm solving this problem. Let $\Pi = (\Pi^o, \Pi', \Pi'')$, where Π^o is the portion of the vector belonging to the constraint, equation (12), Π' is the portion belonging to the constraint, equation (13), and Π'' is the portion belonging to the constraint, equation (14). And let Π_i^o, Π'_i, and Π''_i be the ith element of the respective partial vectors. The prices, $\hat{c}_{ij}$, of the activity vectors, X^{ij}, included in the solution are thus obtained:

[1] See equation (19). Of course, $\sum_i A_i^o X^i = b^o - X^o$, as in the constraint, equation (2).

(15)
$$\hat{c}_{ij} = r^j X^{ij} - \Pi^o A_i{}^o X^{ij} - \Pi'_i (r^j - f A_i{}^o) X^{ij} - \Pi''_i.$$

These ought to be the prices of reformulated programs of the member firms, which are the subprograms, if the cooperative's objective should be achieved. In the next stage, a new vector may enter the basis, one with max $\hat{c}_{ij}$, which will be created from these subprograms defined as follows:

(16)
$$\max_{X^i} Z'_i = (r^j - \Pi^o A_i{}^o) X^i - \Pi'_i (r^j - f A_i{}^o) X^i,$$

and

(17) $$A_i X^i = b^i; X^i \geq 0.$$

After solving each of these problems ($i = 1, \ldots, M$), the new vector entering the basis will be the one with max $\{Z'_i - \Pi''_i\}$. To simplify the analysis, it can be assumed that $\Pi'_i = 0$. This is true if q is small enough.[2] Then, instead of equation (16), the objective function of the firm's problem will be

(18) $$\max_{X^i} Z'_i = (r^j - \Pi^o A_i{}^o) X^i.$$

This procedure will ensure realization of the cooperative's optimum, equation (6), after a finite number of stages. It is dependent on the assumption that the cooperative can calculate the values of the simplex multipliers, Π^o and Π', taking the activity vectors X^i of the firms as given, and rely on the firms to solve problems, equations (16) and (17) or (17) and (18), after being informed of the simplex multipliers' values and act according to these solutions.

This is not, however, the usual procedure in practice. Member firms are not usually informed of the values of the simplex multipliers and are not aware of their importance to the cooperative. According to assumption (*e*), they solve problems, equations (3) and (4) after being informed of the price vector f. Therefore, unless f is identical with Π^o, the behavior of the members will not necessarily be that required to attain the cooperative's optimum.

This discrepancy between the two objective functions, equations (3) and (18), which stems from the nonidentity of f and Π^o, explains the main problem of cooperative management. The firms, acting independently according to their objectives, do not respond automatically to the cooperative's goals and may hinder the cooperative from achieving its optimum. The larger the discrepancy between f and Π^o, the wider will be the distance between the theoretical optimum and the level actually achieved in the system.

Optimum Pricing Policy for Cooperative Resources

The model presents the price vector, f, of the fixed costs of cooperative services as a parameter, dependent on decisions of the cooperative society. The problem emerges therefore as to the optimal f that satisfies the model's objective. It is apparent from the above analysis that this vector does affect the behavior of the member firms.

An optimal pricing policy should fulfill two conditions. First, it must cover the actual expenses of the cooperative society. Fixed costs will be covered, if

(19) $$(b^o - X^o) f + C = F; \qquad C \geq 0;$$

$(b^o - X^o)$ are the amounts of cooperative resources utilized by the firms for which f is charged. C is a fixed quantity which, according to the cooperative's policy, is equally divided among the members. C may be zero, in which case all expenses will be paid in proportion to utilization of resources, or it may be relatively large. Second, it must become a means for attaining the cooperative's objectives.

According to the model presented here, the cooperative's objective is optimal allocation of its resources so as to maximize the aggregate rent of the system. The variable in this primal problem is X (or λ), whereas f would be the variable in the dual problem of determining optimal prices for the cooperative resources which will achieve minimum aggregate payments of member firms, provided that no member's total payment will be less than the rent left to him from the utilization of these resources.[3]

According to the theory of linear programming, the solution of the dual problem is the vector of simplex multipliers, Π^o, of the primal problem, which will therefore be the optimal pricing policy for achieving the cooperative's objectives. They are the shadow prices of the cooperative's resources.

The superiority of the optimal $f = \Pi^o$ over alternative pricing vectors can be illustrated by the case of idle resources. The most popular alternative is the vector of average fixed service costs. According to this procedure, resources that are not fully utilized will be charged higher than when fully utilized, because the total fixed cost is divided by less than the total available quantity. This reduces the demand of members for that resource and increases the idle quantity. The optimum f, on the other hand, includes a zero price for idle resources, and a pricing policy thus adjusted may enhance their utilization.

Nevertheless, $f = \Pi^o$ does not generally fulfill the condition in equation (19) and, as a pricing policy, it will therefore frequently unbalance the budgeting process, leaving a surplus or deficit to be transferred to the members periodically. Eschenburg explained the problems which such unbalanced budgets raise (pp. 108–17).

It is therefore necessary to determine such prices for the cooperative services that result both in a

[2] For accuracy, conditions must be specified in which $\Pi'_i = 0$. However, no loss of generality is incurred if the following analysis is limited to such cases.

[3] Formally, this dual problem is derived from the formulation, equations (11), (12), (13), and (14), of the cooperative's master problem omitting the constraint, equation (13), on assuming $\Pi'_i = 0$, which is the primal problem.

balanced budget and, at the same time, enhance optimal behavior of the member firms (where optimality is defined by the cooperative's objective function). Such optimal behavior will ensue if the objective functions of all member firms—assumed to be equation (3)—are identical with equation (18) or, as we know from the theory of linear programming, if they have a price vector which is proportional to that of equation (18) (i.e., one which ensures identical solutions of the two problems). Hence, a vector f must be found which, in addition to the condition in equation (19), also meets the following condition:

(20)
$$r^i - fA_i^o = \gamma_i (r^i - \Pi^o A_i^o) \qquad (i = 1, \ldots, M).$$

These two conditions form a set of linear equations of the variables $(f_1, \ldots, f_N, \gamma_1, \ldots, \gamma_M)$. It does not have a solution in most cases as the number of equations is usually larger than the number of variables, and additional constraints do exist:

$$(21) \quad (\gamma_1, \ldots, \gamma_M) > 0; \qquad (f_1, \ldots, f_N) \geqslant 0.$$

Nevertheless, the cooperative society can find a price vector f which will avoid severe departure from optimal allocation of resources by fulfilling these conditions with reasonable approximation. A possible approximation is to find a vector f proportional to Π satisfying equation (19) and then make adjustments of prices f so as to avoid large deviations from the proportionality of surplus, equation (20).[4]

Finally, it should be noted that the model defines the values, Π^o, of the marginal productivity of cooperative resources. Knowledge of these values is of the utmost importance for a developing cooperative which requires investments for widening its services. These values determine the profitability of investment and may be used by the cooperative's management as an instrument for decision making. They are obviously results of the definition of the cooperative's objective function.

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[4] A significant case which has a solution is of members who have similar enterprises so that their technological matrices can be assumed to be identical. Equation (20) becomes $r - fA^o = \gamma (r - \Pi^o A^o)$. If the number N of cooperative services is equal or larger than the number t of possible production activities than with equation (19), the number of variables $N+1$ is at least equal to the number of equations $t + 1$. However, it is not determined whether the solution is nonnegative.

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The Composition Ratio, Returns to Scale, and the Effect of Concentration on Production

L. Shashua and Y. Goldschmidt

A composition ratio has been introduced in this *Journal* by Shaw and later used by Shaw and Arden to analyze sectoral productivity change and sectoral shifts. The idea behind the composition ratio, R, is simple; it is the ratio between aggregate productivity and sectoral simple average productivity. The objective of this paper is to show that this ratio, when calculated for a single sector, has further meanings. The ratio indicates the existence of returns to scale, and it measures the effect on aggregate production due to size concentration (size differences) and productivity distribution (factor productivity differences) among firms.

Formal Definition of R

Let

$$Y^*_i = \frac{Y_i}{X_i},$$

where Y and X denote two random variables, e.g., Y^*_i = labor productivity when Y denotes product and X denotes labor, all for the ith firm. The simple and aggregate averages of Y^* are defined as follows:

$$Y^{*\prime}_s = \frac{\Sigma\, Y^*_i}{n},$$

the simple average of Y^* over the n firms in the sector, and

$$Y^{*\prime}_w = \frac{\Sigma\, Y_i}{\Sigma\, X_i} = \frac{\Sigma\,(Y^*_i\, X_i)}{\Sigma\, X_i}$$
$$= \Sigma\left[Y^*_i\left(\frac{X_i}{\Sigma\, X_i}\right)\right] = \Sigma\,(Y^*_i \cdot w_i).$$

Thus, $Y^{*\prime}_w$ is the weighted or aggregate average where the weights are given by $w_i = X_i/\Sigma\, X_i$. The composition ratio as defined by Shaw is

$$R = \frac{Y^{*\prime}_w}{Y^{*\prime}_s}, \tag{1}$$

which is the ratio between the aggregate productivity and the simple average productivity.

The mathematical relation between the weighted and the simple average is developed in Yule and Kendall (p. 344):

$$Y^{*\prime}_w = Y^{*\prime}_s + r\,\sigma_{y^*} \cdot \frac{\sigma_w}{w'}, \tag{2}$$

where w' is the average of the w_i. In our case, $w' = 1/n$ and r is the correlation Y^* and w which is the same as the correlation between Y^* and X since w equals X divided by a constant ($\Sigma\, X_i$). The σ's denote the standard deviations. Dividing equation (2) by $Y^{*\prime}_s$ and substituting C_w and C_x, where the C's denote the coefficients of variation,

$$R = 1 + rC_{y^*}C_x. \tag{3}$$

In other words, R is affected by the correlation between Y^* and X and their relative dispersions. When r is positive, R is larger than unity since the coefficients of variation are always positive. In the case of a production function, increasing productivity with respect to scale indicates increasing returns ($r > 0$), and therefore $Y^{*\prime}_w > Y^{*\prime}_s$. Decreasing returns occur when Y^* decreases with the scale of X; thus $r < 0$ and $R < 1$. In other words, r indicates the existence of returns to scale.[1] C_{y^*} indicates the inequality in the productivity of firms, while C_x can be considered as a measure of size concentration. The higher C_{y^*} and C_x, the larger is the deviation of R from unity. The effect of C_x and C_{y^*} on R for a given positive level of r ($r = 0.7$) is illustrated in figure 1. The relations are linear in accordance with equation (3).

The Effect of Concentration on Aggregate Production

The magnitude of a change in the aggregate production of a sector due to size differences among firms, that is, due to concentration, is often an important policy issue. Returns to scale indicate the sign of this change, favorable or unfavorable, but it cannot assess its magnitude. The total change depends on the degree of returns and on the size distribution of firms. On the other hand, the composition ratio (R) is a suitable measure for the effect of concentration.

Assume that the production process of Y can be described by a homogeneous production function of degree t in capital (K) and labor (L):

$$Y_i = f(K, L) = L_i^t\, F\!\left(\frac{K}{L}\right) \text{ for the } i\text{th firm.} \tag{4}$$

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[1] While the sign of r indicates the existence of returns to scale, it does not indicate the magnitude of returns to scale.

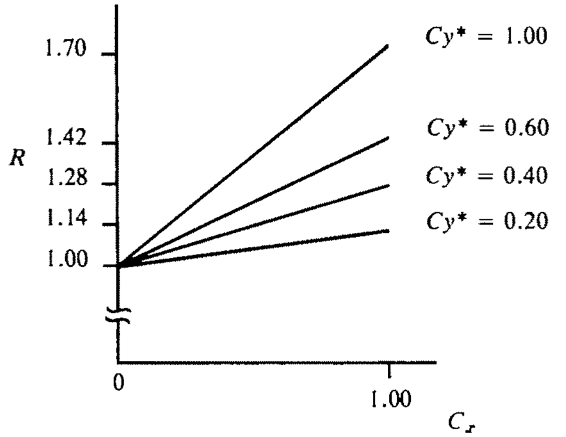

Figure 1. The effect of concentration on the composition ratio

Dividing both sides of equation (4) by L,

(5) $Y^*_i = L_i^{t^*} F(K^*_i) = g(L_i, K^*_i)$,

where Y^*, K^* denote Y/L and K/L respectively, and $t^* = t - 1$. Further, denote $Y^{*\prime}_w = \Sigma\, Y_i / \Sigma\, L_i$, the aggregate average labor productivity of the sector; $Y^{*\prime}_s = \Sigma\, Y^*_i/n$, the simple average labor productivity over the firms; and $Y^{*\prime} = L^{t^*\prime} F(K^*)$, the labor productivity of the average firm, where L', K' are the average levels of the inputs. Then, the relative change in aggregate production due to size distribution is

(6) $$\Delta = \left(\frac{Y^{*\prime}_w - Y^{*\prime}}{Y^{*\prime}}\right) = \frac{Y^{*\prime}_w}{Y^{*\prime}} - 1;$$

Δ indicates the relative gain or loss in total production of the sector if the firms were of equal size.

Since $R = Y^{*\prime}_w / Y^{*\prime}_s$, then $R - 1$ would indicate the size of Δ when $Y^{*\prime}_s$ approximately equals $Y^{*\prime}$. To show this, we perform a Taylor expansion[2] on Y^*_i of equation (5) around the averages of L and K^*, and we take expectations

(7) $$Y^{*\prime}_s \simeq Y^{*\prime} + \frac{1}{2} g_{11}\, \sigma_L^2 + \frac{1}{2} g_{22}\, \sigma_{K^*}^2 + r_{12}\, g_{12}\, \sigma_L\, \sigma_{K^*},$$

where g_{11}, g_{22}, and g_{12} indicate the second derivatives with respect to L, K^*, and L, K^*, respectively, and where σ^2 is the variance and r_{12} is the correlation coefficient between L and K^*.

In order to show the magnitude of the deviation of $Y^{*\prime}_s$ from $Y^{*\prime}$, we apply equation (7) to a Cobb-Douglas production function,

(8) $$Y^*_i = A\, L^{t^*}_i\, K^{*a}_i.$$

We receive the relation deviation, D,

(9) $$D = \frac{1}{2}\, t^*(t^* - 1)\, C_L^2 + a(a - 1)\, C^2_{K^*} + r_{12}\, t^*\, a C_L C_{K^*},$$

where the C's are the coefficients of variation,

$$D = \frac{Y^{*\prime}_s - Y^{*\prime}}{Y^{*\prime}}.$$

Using equation (9), the magnitude of the deviations (D) are calculated in table 1[3] for various levels of r_{12} and for increasing and decreasing returns ($t^* > 0$ and $t^* < 0$, respectively), assuming the following parameters:

$$t^* = 0.3 \text{ and } -0.3;\ a = 0.5;\ C_L = C_K = \frac{1}{3}.$$

The results of the computations show that the relative deviations for the assumed parameters are rather small, up to 3.6%. The deviation is higher in the case of increasing returns and also higher for the case of negative r_{12}.[4]

The above analysis shows that the aggregate change in a sector due to size distribution is given approximately by $R - 1$. On the other hand, if scale redistribution leaves Y^*_i for every firm unchanged, then $R - 1$ is an exact measure of the aggregate change. This may happen when differences in Y^*_i are due not to the effect of scale but to other factors such as management, product mix, regional effects, etc.

Table 1. Calculated D for Various r_{12}'s

	Assumed r_{12}				
	−0.6	−0.2	0	0.2	0.6
For t^* = 0.3	−0.036	−0.029	−0.026	−0.022	−0.016
For t^* = −0.3	0.018	0.010	0.008	0.004	−0.002

[2] Taylor's expansion of

$$Y^* = g(x_1, x_2),$$

when $x_1 = L$, $x_2 = K^*$ is

$$g(x_1, x_2) \simeq g(x'_1, x'_2) + \sum_i \frac{\partial g}{\partial x_i}\bigg|_{x'} (x_i - x'_i) + \frac{1}{2} \sum_{ij} \frac{\partial g^2}{\partial x_i\, \partial x_j}\bigg|_{x'} (x_i - x'_i)(x_j - x'_j) \quad i,j = 1,2,$$

dropping terms of higher than second degree. Taking expectations of the above equation with respect to x and recalling that the expectation of the difference between a variable and its expectation is zero,

$$E[g(\cdot)] \simeq g(Ex_1, Ex_2) + \frac{1}{2} \sum_{ij} \frac{\partial g^2}{\partial x_i\, \partial x_j}\bigg|_{x'} \operatorname{cov}(x_i, x_j)$$

and

$$\operatorname{cov}(x_i, x_j) = r\, \sigma_i\, \sigma_j.$$

[3] Calculating D for various levels of r has been suggested by one of the reviewers.

[4] The correlation between L and K^* (r_{12}) is expected to be negative in the case of a true intrafirm production function because we expect substitution between K and L. On the other hand, r_{12} is expected to be positive in the case of an interfirm production function. When there exist differences of age, technology, management, etc., among firms, then a certain capital-deepening process is expected.

Summary

While Shaw and Arden used the intersectoral composition ratio to analyze sectoral productivity changes, we use this ratio for any single sector. We found that the sector's composition ratio is affected by three factors: (*a*) the extent of returns to scale, (*b*) the dispersion of productivity among firms, and (*c*) the size distribution of firms. The deviation of R from unity measures the overall effect of concentration on the sector's total production; its value equals the product of the three factors. The measure R is an important parameter in understanding aggregation relationships and may be included as an explanatory variable in the analysis of aggregate intersectoral production functions.

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A Bayesian Application on Cobb-Douglas Production Function

S. Roy Chowdhury, Vishnuprasad Nagadevara, and Earl O. Heady

Cobb-Douglas production functions estimated by least-squares methods have been widely applied in agriculture. Estimates based on cross-sectional samples of farms, as most studies have been, almost typically result in some elasticities for land and labor which are negative. These negative coefficients, which are meaningless, can arise for several reasons. One is the prevalence of multicollinearity in random or unstratified farm samples where farmers with large labor inputs also are those with larger inputs of land and various forms of capital. (A farm sample stratified by the various input categories and magnitudes much in the manner of a factoral, central composite or other experimental designs to estimate the physical production surface, would not encounter this problem to the extent of the typical farm survey.) Another reason is reporting or measuring bias. For example, regardless of whether he actually does so, a farmer generally will report that he works twelve months per year; he is unlikely to concede that he is idle part of the time. Finally, other inadequacies of data also pose the potential of negative labor elasticities in Cobb-Douglas functions and are hard to explain under existing knowledge. These negative coefficients confuse the analysis and leave the researcher more or less empty-handed. Among others obtaining these results, Sahota simply considered his results absurd and Srivastava and Nagadevara could not attempt to explain theirs. The production function analysis conducted by Agrawal and Foreman, and Suryanarayana also resulted in negative elasticities for labor and capital services. Heady and Dillon and, recently, Doll have proposed reasons for the prevalence of negative elasticities. We attempt to resolve the problem of negative elasticities with a Bayesian model incorporating relevant prior restrictions.

Least-Squares Model

The model to be estimated is based on a production function from Srivastava and Nagadevara. The data pertain to the production of Desi wheat in Ferozpur district, Punjab (India) for the year 1968–69. The original sample included 150 farmers selected on a stratified random basis. From the 150 farmers, a cross-section sample of 90 farmers producing the Desi variety was selected. The production function estimated is of the form,

$$y_i = A\, x_{1i}^{\beta_1}\, x_{2i}^{\beta_2}\, x_{3i}^{\beta_3}\, e^{u_i}, \tag{1}$$

where y_i = output of Desi wheat (rupees) of the ith farm, x_{1i} = area of the ith farm under wheat production (hectares), x_{2i} = human labor (adult man days) used by the ith farm, x_{3i} = value of seeds and fertilizers (owned and purchased) used by the ith farm (rupees), and u_i are random disturbances.

The variables used here are slightly different from those of Srivastava and Nagadevara. They included irrigation charges in x_3 whereas we do not. For this reason, our estimates will differ from theirs when least-squares estimation is applied (table 1).

Elasticity of land, given by the estimate of β_1, is negative possibly due to the existence of multicollinearity. Existence of multicollinearity can be detected by examining the correlation matrix of x_1, x_2, and x_3 and its inverse which are given in equations (2) and (3), respectively:

$$\begin{bmatrix} 1.000 & 0.814 & 0.808 \\ 0.814 & 1.000 & 0.861 \\ 0.808 & 0.861 & 1.000 \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} 3.419 & -1.561 & -1.420 \\ -1.561 & 4.589 & -2.691 \\ -1.420 & -2.691 & 4.466 \end{bmatrix} \tag{3}$$

Tests performed on the determinant of the correlation matrix and main diagonal elements of the inverse of the correlation matrix show the presence of multicollinearity. To obtain acceptable estimates of the parameters we adopt a Bayesian model.

Bayesian Model

Bayesian analysis has been applied on Cobb-Douglas production function models by Zellner, Kmenta, and Dreže who specified "noninformative" prior distributions for the parameters. In our model we use "informative" prior distributions instead since definite information about the bounds of some of the parameters were available beforehand.

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Table 1. Least Squares Estimates of the Parameters

	Estimates of the Coefficients[a]				
Method	Log A	β_1	β_2	β_3	R^2
Least squares	−0.246	−0.158	0.946	0.218	0.93
	(−0.264)	(−0.814)	(5.118)	(1.213)	

[a] The t-values are given in parentheses.

For this reason, the estimation method in our model differs from theirs.

In our Bayesian model the elasticities of land, labor, and fertilizer are taken to be nonnegative. Also, from analysis conducted elsewhere and from the existing knowledge in agriculture, we firmly believed that the elasticities do not exceed unity. No extra restriction is imposed on the returns to scale other than the one through the restrictions on the elasticities. Based on the above observations, the prior restrictions on the parameters in equation (1) are

(4) $$0 \leqq \beta_1 \leqq 1,$$

(5) $$0 \leqq \beta_2 \leqq 1,$$

and

(6) $$0 \leqq \beta_3 \leqq 1.$$

The model in equation (1) can be rewritten as

(7) $$z_t = \beta_0 + \beta_1 y_{1t} + \beta_2 y_{2t} + \beta_3 y_{3t} + u_t,$$

where $z_t = \log y_t$, $y_{1t} = \log x_{1t}$, $y_{2t} = \log x_{2t}$, $y_{3t} = \log x_{3t}$, and $\beta_0 = \log A$. The disturbances u_t are assumed to be independently and normally distributed with zero means and variances σ^2. In vector form, equation (7) can be written as:

(8) $$z = \beta_0 l + \beta_1 y_1 + \beta_2 y_2 + \beta_3 y_3 + u,$$

where z, y_1, y_2, y_3, and u are column vectors of observations and disturbances. The vector l is a column vector whose elements are all equal to unity. The likelihood function based on equation (8) is

(9) $$L = \frac{1}{\sigma^n (2\pi)^{n/2}} \exp\left\{-\frac{1}{2\sigma^2}[(n-4)S^2 + (\beta - \hat\beta)' y'y (\beta - \hat\beta)]\right\}$$

where $\beta' = (\beta_0, \beta_1, \beta_2, \beta_3)$, $\hat\beta$ is the least-squares estimator of β, and y is an $n \times 4$ matrix of observations of explanatory variables. The expression,

(10) $$(n-4)S^2 = (z - y\hat\beta)'(z - y\hat\beta),$$

is the usual residual sum of squares for least-squares estimation, and n, which is the number of farms, is equal to 90 in our model. Without loss of generality, let $(\beta - \hat\beta)'$ and $y'y$ be partitioned as

(11) $$\delta'_1 = (\beta_1 - \hat\beta_1, \beta_2 - \hat\beta_2, \beta_3 - \hat\beta_3) \text{ and } \delta'_2 = (\beta_0 - \hat\beta_0),$$

and

(12) $$y'y = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}.$$

With this partitioning, the likelihood function in equation (9) can be written as

(13) $$L = \frac{1}{\sigma^n (2\pi)^{n/2}} \exp\left\{-\frac{1}{2\sigma^2}[(n-4)S^2 + \delta'_1(h_{11} - h_{12}h_{22}^{-1}h_{21})\delta_1 + (\delta_2 + h_{22}^{-1}h_{21}\delta_1)'h_{22}(\delta_2 + h_{22}^{-1}h_{21}\delta_1)]\right\}.$$

Prior Distribution

In the Bayesian analysis, the following prior distribution is used for the parameters $\beta' = (\beta_0, \beta_1, \beta_2, \beta_3)$ and σ:

(14) $$p(\beta', \sigma) \propto p_1(\beta')p_2(\sigma),$$

where

(15) $$p_1(\beta') \propto \text{constant with } 0 \leqq \beta_1 \leqq 1, \; 0 \leqq \beta_2 \leqq 1, 0 \leqq \beta_3 \leqq 1,$$

and

(16) $$p_2(\sigma) \propto \frac{1}{\sigma}.$$

In equations (14), (15), and (16), we follow Jeffreys, Tiao and Zellner, and Zellner. Ignorance about σ^2 is expressed in equation (16) in accordance with Jeffreys's invariance theory (p. 459).

Now using Bayes's theorem to combine the prior distribution in equations (14), (15), and (16) with the likelihood function in equation (13), the joint posterior distribution of the parameters is

(17) $$p(\beta_0, \beta_1, \beta_2, \beta_3, \sigma) \propto \frac{1}{\sigma^{n+1}} \exp\left\{-\frac{1}{2\sigma^2}[(n-4)S^2 + \delta'_1(h_{11} - h_{12}h_{22}^{-1}h_{21})\delta_1 + (\delta_2 + h_{22}^{-1}h_{21}\delta'_1)h_{22}(\delta_2 + h_{22}^{-1}h_{21}\delta_1)]\right\},$$

where $0 \leqq \beta_1 \leqq 1$, $0 \leqq \beta_2 \leqq 1$, $0 \leqq \beta_3 \leqq 1$.

Integrating equation (17) with respect to β_0 and σ successively gives the following marginal posterior distribution of β_1, β_2, and β_3:

(18) $$p(\beta_1, \beta_2, \beta_3) \propto [(n-4)S^2 + \delta'_1(h_{11} - h_{12}h_{22}^{-1}h_{21})\delta_1]^{-(n-1)/2};$$
$$0 \leqq \beta_1 \leqq 1, 0 \leqq \beta_2 \leqq 1, 0 \leqq \beta_3 \leqq 1.$$

The marginal posterior distribution $p(\beta_1, \beta_2, \beta_3)$ is multivariate t but truncated.

Bayesian Estimates of the Parameters

Two possible methods can be suggested to obtain the Bayesian point estimates of the parameters. The first method which maximizes the posterior

distribution will give modes as the estimates. This method resembles maximum likelihood estimation. The second method will give posterior means as the estimates which are optimal when the loss function is a quadratic one.

When the marginal posterior distribution, equation (18), is maximized with respect to β_1, β_2, and β_3 to obtain the modes, essentially the following quadratic programming problem is solved:

$$(19) \min (\beta_1 - \hat{\beta}_1, \beta_2 - \hat{\beta}_2, \beta_3 - \hat{\beta}_3)(h_{11} - h_{12}h_{22}^{-1}h_{21})(\beta_1 - \hat{\beta}_1, \beta_2 - \hat{\beta}_2, \beta_3 - \hat{\beta}_3)',$$

subject to $0 \leqq \beta_1 \leqq 1$, $0 \leqq \beta_2 \leqq 1$, and $0 \leqq \beta_3 \leqq 1$.

In our example, application of quadratic programming procedure, equation (19), gives zero as the mode of β_1. This is what it should be because truncation of β_1 occurs at zero. A zero estimate for β_1 is not very interesting, at least not in our case.

As suggested in the second method, posterior means and posterior variances of β_1, β_2, and β_3 are obtained from equation (18) by numerical integrations over the restricted space of β_1, β_2 and β_3. Posterior mean of β_0 is obtained from the following relation derived from equation (17) after simplification:

$$(20) \quad \tilde{\beta}_0 = \hat{\beta}_0 - h_{22}^{-1}h_{21}[(\tilde{\beta}_1 - \hat{\beta}_1), (\tilde{\beta}_2 - \hat{\beta}_2), (\tilde{\beta}_3 - \hat{\beta}_3)]',$$

where $\tilde{\beta}_0$, $\tilde{\beta}_1$, $\tilde{\beta}_2$, and $\tilde{\beta}_3$ are posterior means of β_0, β_1, β_2, and β_3. Table 2 summarizes the results of the Bayesian estimates.

Results obtained by the Bayesian approach are consistent with prior knowledge. Also, the posterior variances of β_1, β_2, and β_3 are lower than the variances given by least squares. Besides correcting β_1, the Bayesian approach also corrected other coefficients. We believe that more correct estimates of all the parameters are obtained by the Bayesian approach. Our belief is based on the premise that multicollinearity usually distorts the estimates of all the parameters and not just one. Restricted least squares also yields point estimates of the parameters in cases where there are inequality constraints. The Bayesian method has an added advantage because it gives explicit posterior probability distribution and posterior means and variances of the parameters. Also, the Bayesian method can incorporate different types of prior distributions other than uniform. In any case, restricted least squares will give zero estimate for β_1 in our example.

Table 2. Bayesian Estimates of the Parameters

Method	Estimates of the Coefficients β_0	β_1	β_2	β_3
Posterior mean	0.871	0.128	0.767	0.208
Posterior variance		0.006	0.018	0.014

Conclusions

The method of estimation given in the preceding sections is quite general and is applicable to the class of problems in regression analysis when a subset or all of the parameters are known to lie within certain ranges based on a priori knowledge and when least squares produce results which are inconsistent with that knowledge. Prior distributions other than uniform can also be taken. Computational problems involving numerical integrations become increasingly difficult with the increase in the number of parameters, although they are not impossible to handle on large computers.

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Canadian Supply Functions for Livestock and Meat: Comment

Thomas E. Elam

In an article by Tryfos, a simultaneous equation model of Canadian livestock supply response was presented. While this study may give important insights into the structure of the sector under consideration, it contains an error which requires comment before a correct interpretation of the empirical results can be made. Specifically, the explanation for positive price coefficients estimated for the inventory equations of the model demands closer scrutiny.

Tryfos rationalizes his results on the premise that current price may be used as a proxy variable for expected price (p. 108). Thus, an increase in current slaughter animal price would prompt producers to increase inventories and reduce current supply to slaughter markets in order to take advantage of expected increases in gross revenues. Unfortunately, Tryfos ignores the fact that an increase in current price can be shown to have a negative effect upon ending inventories which is independent of any expectational effects created by that price increase.

Myers and Havlicek have presented a theoretical model of the monthly supply response of livestock producers. Their model was based on a somewhat shorter time period of observation than the yearly data used by Tryfos, but nonetheless the two studies are identical in basic concept. Specifically, it is fundamental to both Myers and Havlicek, and Tryfos that livestock inventories at the beginning of a period are predetermined, whereas ending inventories (and thus, to an extent, supply for slaughter) are partially determined by movements in current and near-term expected price. With respect to the appropriate treatment of expected price, the studies differ, however.

Myers and Havlicek treat expected price as an explicit variable which is affected by, but not perfectly correlated with, current price (p. 1300). Not surprisingly, they arrive at the theoretical conclusion that increases in current (expected) price have positive (negative) effects on current slaughter (p. 1399). Implicit in this conclusion is the statement that changes in current (expected) price have negative (positive) effects on ending inventories. They further conclude that within the context of their theoretical model when expected price is omitted, the total effect of current price on current slaughter supply is the sum of two coefficients—one positive (representing current price effects) and one negative (representing the fact that expected and current price are likely to be positively correlated) (p. 1400).

Tryfos, on the other hand, considers only the anticipatory effects of a change in current price, ignoring possible current period effects (p. 108). It may well be true that the effects of change in current price on ending inventories and current supply are swamped by anticipation effects created by those changes, but this is an empirical matter and not one which can be assumed a priori.[1]

A method of dealing with this problem is suggested in the author's doctoral dissertation. In this study (based on 1964–71 monthly U.S. data), cattle and hog producers are assumed to form near-term expectations based on recent trends. To be more specific, the expected price per hundredweight for cattle and hogs in month t is specified as a linear function of respective near-past prices:

$$EP_t = a + b_1P_{t-1} + b_2P_{t+2} + b_3P_{t-3}. \tag{1}$$

Utilizing actual price data for period t as the dependent variable, two ordinary least-squares estimates for parameters of equation (1) were computed, one for cattle and the other for hogs. Predicted values for EP_t for cattle and hogs were calculated from the estimated regression equations. Expected gross returns per hundredweight from holding inventory versus immediate sale (EP'_t) were then computed for both cattle and hog price series by subtracting price for month t from "expected" (predicted) price for month $t + 1$.

A model of cattle and hog supply was constructed (Elam, pp. 16–20) (all variables are for month t; thus, this subscript is omitted below):

$$Q_s = f(EP', I, P_f, T, M),$$

where Q_s = commercial slaughter, liveweight basis, millions of pounds; EP' = "expected" price per hundredweight in month $t + 1$ less current price per hundredweight, deflated by the wholesale price index; I = beginning inventories, number of head; P_f = feed price (#2 yellow corn deflated by the wholesale price index); T = time trend $(1, 2, \ldots, T$ for T months of data); and $M = 0, 1$ intercept dummy variables for months (January excluded).

Coefficients of EP' were expected to be negative, while those for I, P_f, and T were expected to be positive. Empirical results, based on two-stage

[1] If the effects of changes in current prices are consistently swamped by price expectation effects created by those changes, one must ask why theory does not postulate positively sloped demand curves and negatively sloped supply curves and a situation of general instability.

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least squares, bore out these expectations with the coefficients for EP' equal to -57.246 and -60.979 for the cattle and hog supply equations respectively (Elam, p. 51, 57).[2] Thus, a statistical model which explicitly takes into account both current and expected prices would predict that an increase in current price not matched by an increase in expected price would tend to increase current slaughter.

In closing, it should be noted that in this author's opinion the definitive work on short-run livestock supply response remains an elusive goal. In particular, much work is yet to be done on the relative importance of near-term price expectations in explaining current supply. The principal impediment to such a study has been in the past and will likely be in the future a universally acceptable model of the formation of price expectations.

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[2] Standard errors for these coefficients were 49.756 and 32.990, respectively.

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Canadian Supply Functions for Livestock and Meat: Reply

Peter Tryfos

The model presented in an earlier issue of this *Journal* was based on three assumptions: (*a*) for suitably short periods of time, the quantity of livestock available does not depend on prices and feed costs; (*b*) slaughter (and, in Canada, exports) represents the part of the quantity available which is not used to satisfy the demand for inventory change; and (*c*) current prices and feed costs can be used as proxy variables for expected prices and costs. The approach used follows largely Reutlinger's except that inventories as well as supply are simultaneously estimated.

As Elam correctly points out, (*b*) and (*c*) are behavioral assumptions; there are circumstances (for example, high current prices accompanied by low expected prices) where at least one of the assumptions does not hold and the assumed effects would not be correct. However, the assumptions are not unreasonable as descriptions of aggregate behavior; they lead to a simple model of inventories and supply; the empirical estimates are consistent with the model; and the fit of the estimated equations to the actual time series is rather good. In judging a study, all these elements must be considered.

Elam's comments indicate that there is need to clarify the relationship between present and expected prices and differences between individual and aggregate behavior. In particular, he appears to read into the Myers and Havlicek model perhaps more than the authors intended to convey. A careful study of the article shows that the conclusions are qualified by several conditions and that the treatment of expected prices is not the only one possible. Therefore, it may be worthwhile to derive the postulated aggregate behavior from a simple model of individual supply response. The model is a simplified version of the Myers and Havlicek model, made deliberately simple in order to prevent the mathematical problems from obscuring the basic economic rationale.

An individual producer has a quantity of livestock (N), excluding breeding stock, available at the beginning of the current period. Livestock not slaughtered during the current period ($n_2 = N - n_1$, where n_1 is the number slaughtered during the current period) must be slaughtered during the next period. Let P be the unit live price of slaughter livestock during the current period and P^* the discounted expected price in the next period; let C be the unit cost of carrying livestock during the current period and C^* the discounted expected unit carrying cost during the next period. The producer's expected profit is

$$V = n_1 (P - C) + n_2 (P^* - C^*).$$

Setting $n_1 = N - n_2$ and combining terms,

$$V = N(P - C) + n_2 [(P^* - P) - (C^* - C)],$$

where $O \leqslant n_2 \leqslant N$. Clearly, if the expected price change, $\Delta P^* = P^* - P$, is greater than the expected cost change, $\Delta C^* = C^* - C$, the producer maximizes profits if $n_2 = N$; if $\Delta P^* < \Delta C^*$, profits are maximized when $n_2 = 0$. The producer's supply function for the current period, $n_1 = N - n_2$, is of the "all-or-nothing" type, $n_1 = 0$ if $\Delta P^* > \Delta C^*$ and $n_1 = N$ if $\Delta P^* < \Delta C^*$. (A different cost function may "dampen" the supply response.) *Ceteris paribus*, an increase in expected price (P^*) will have a negative effect on current supply, in the sense that it will cause a curtailment of current supply if the latter was positive. Similarly the effects on current supply of an increase in current price (P) or in expected cost (C^*) are positive, while the effect of an increase in current cost (C) is negative. These conclusions, obvious in the context of this simple model, are those also reached by Myers and Havlicek (p. 1399).

These are, however, implications for an individual producer's response; the aggregate behavior remains to be examined. Each producer forms an expectation on prices and costs. The aggregate supply is the sum of supplies by producers who believe that the price change ΔP^* will be lower than the cost change ΔC^*. For simplicity, we may take the producers' initial inventories to be approximately equal, in which case the quantity supplied is greater the greater the fraction of producers who believe that ΔP^* will be lower than ΔC^*; the reverse applies to ending inventories.

It is generally felt that present prices and costs play an important role in determining expectations on future prices and costs, but there is little research and no unanimity as to precisely how this is done. It may be reasonable to assume that, for given cost expectations, the fraction of producers who believe that the price next period, P^*, will exceed the current price, P, by any specified margin (e.g., ΔC^*) is larger, the higher the level of current price; similarly, for given price expectations, the fraction of producers who believe that future cost will exceed current cost by any specified margin will be larger, the larger the level of current cost C. If these assumptions are met, the approxi-

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Table 1. Partial Monthly Supply Estimates, Canada

Dependent Variable: Inspected Slaughter of:	Explanatory Variables: Inventories		Live Price	Feed Cost	Other Statistics: n	$\hat{\rho}$	$\bar{R}^2$	d
Cattle	4.294		−0.804	0.159	192	0.502	0.93	2.21
	(11.48)		(−1.25)	(1.63)				
Calves[a]	1.125	3.194	−0.458	0.027	192	0.793	0.92	2.09
	(1.08)	(1.94)	(−1.26)	(0.41)				
Pigs	10.181		−3.402	1.017	192	0.545	0.91	2.16
	(13.67)		(−2.98)	(4.28)				
Lambs	4.140		0.231	−0.017	192	0.730	0.89	1.57
	(3.36)		(0.58)	(0.17)				

[a] In the case of calves, two inventory variables are used: calves and dairy cattle.

mate relationship between end-of-period aggregate inventories (I) on the one hand and price and cost on the other can be approximated by

$$I_t = b_0 + b_1 P_t + b_2 C_t,$$

where $b_1 > 0$ and $b_2 < 0$. This is the form of equation (2) and the starting point for the model of aggregate behavior in Tryfos (1974a, p. 108).

It is difficult to see why Elam's empirical contribution contradicts any of the above hypotheses. Even if his particular definition of "expected price" is accepted (obviously, this, too, is a hypothesis), Elam shows that less tends to be supplied when the expected price change is positive—a proposition made earlier in this reply. It would be interesting to see the results of his analysis with actual price (P) replacing $P^*_{e\Delta}$. Since these are not provided, it may be worthwhile to examine the almost equivalent estimates obtained using Canadian monthly data for the period 1955–70. Four regressions were estimated, corresponding to cattle, calves, pigs, and lambs; in each, inspected slaughter for the month (S_t) was the measure of the quantity supplied, the dependent variable; the explanatory variables were inventories at the beginning of the month (I_{t-1}), live price (P_t) and feed cost (C_t) during the month, a time trend (T), and monthly dummy variables (M). The linear model,

$$S_t;\ I_{t-1}P_tC_tT,M,$$

was estimated by ordinary least squares adjusted for serial correlation. The regression coefficients and the corresponding "t-values" for the first three variables are shown in table 1 together with summary statistics; the complete results may be found in Tryfos (1974b).

With the exception of the case of lambs (which, as explained in Tryfos [1974b], may be treated as a special case), all price coefficients are negative and all inventory and feed cost coefficients are positive; the results are thus consistent with the model and with the results based on annual data.

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Migration Analysis and Farm Number Projection Models: A Synthesis: Comment

O. A. Cleveland, Jr. and Michael S. Salkin

In a recent article, MacMillan, Tung, and Tulloch applied a Markov algorithm to migration analysis and farm number projection. Initial projections were based on a constant transition probability matrix with further projections resulting from use of a nonstationary matrix. The projections obtained using Markov chains, as well as the regression results, are ambiguous. The purpose of this comment is to clarify these ambiguities.

First, two conditions of Markov theory with respect to any transition matrix are (Kemeny et al., p. 385)

(1) $P_{ij} \geq 0$, for all i and j,

and

(2) $\sum_{j=1} P_{ij} = 1$, for all i.

Equations (1) and (2) require elements of a transition matrix to be nonnegative and the sum of entries in each row to be one. Therefore, each row is termed a probability vector.

Consider the transition probabilities matrix for Manitoba, P_0, (MacMillan, Tung, and Tulloch, p. 293) and note the first probability vector. All elements are zero, thus violating equation (2) above. For P_0 to be a transition probabilities matrix, all row vectors have to sum to one.

In deriving an initial starting state, one assumption MacMillan, Tung, and Tulloch make is that "any decrease in any income state means that those farms go out of farming (to state S_1)" (p. 293). This assumption implies that the probability of a farm ceasing operation is one if there is a decline in that farm's income category; therefore, the farm will go out of business (to state S_1). To be both theoretically correct and consistent with their assumption, element P_{11} of matrix P_0 must be 1.0. No mention is made about absorption and the resulting implications for S_1 and S_7 in the long run.

Projections presented in table 1 (MacMillan, Tung, and Tulloch, p. 294) are confusing because the numbers presented in the "Leaving Agriculture" size category are net differences between time periods rather than projections. Actual projections for "Leaving Agriculture" could not be obtained directly from the Markov technique using matrix P_0. MacMillan, Tung, and Tulloch indirectly indicate this in footnote c, table 1. As stated, they do not give actual projections for this category but "net reduction since previous census" (p. 294). Yet, in 1976 and 1981, projections for "Leaving Agriculture" cannot be referred to as net reduction since previous census because such a census has not been conducted. Actual Manitoba projections for "Leaving Agriculture" are 5,871, 7,374, and 8,351 for 1971, 1976, and 1981, respectively. The correct transition probability matrix would allow all projections to be calculated directly. These projections are of primary importance in their study and should have been reported.

A second criticism is directed to the usefulness of the projections resulting from their nonstationary transition probabilities. They present percentage errors for the total number of farms projected by both models, and state that "projections for 1971 based on the adjusted matrix have a substantially lower percentage error in five out of seven classes . . ." (p. 297). However, it is not the total number of farms that should draw focus but rather individual size categories since the authors indicate interest in "low income problems of farm operators . . ." (p. 292). Also, the aggregation of positive and negative percentage errors yielding a low total percentage error of prediction is not valid. To indicate the effectiveness of the Markov tool as a predictive device, individual size class projections should show little variance from actual size class numbers. Projections based on the adjusted matrix are of no more use than those based on the constant transition matrix. A comparison of percentage errors of MacMillan, Tung, and Tulloch's models show errors of the adjusted model to be generally lower. However, only one projection, S_4, of the adjusted model was within 10% of the actual while others ranged from −47.15% to 39.20%. The total error is 4.26% but is not of great interest in analyzing problems associated with low income operators. Percentage errors of projections based on constant probabilities ranged from −104.28% to 43.58% with only the projection for S_4 within 10% of actual. The projection power of the tool as employed with these data was poor and MacMillan, Tung, and Tulloch should have exposed and dealt with this fact.

The regression analysis performed by MacMillan, Tung, and Tulloch is, in our opinion, subject to

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Suggestions by Daryll E. Ray have improved the quality of the comment.

criticism on both econometric and explanatory grounds. First, the dependent variable is not clearly defined. The dependent variable, ΔS_t, is first defined as the net change in farm numbers (p. 295) and is later defined as the number of farm operators by size class (p. 295). We are unclear whether they are measuring the number of farmers in different size classes or the number of farms. Our guess is the former since most regressors are more characteristic of people than farms.

The explanation of why signs on the exogenous variables emerged in the manner they did is not adequate. For every regressor statistically significant coefficients emerged with signs opposite of a priori expectation. For ΔX_1, change in off-farm work, the authors offer a plausible explanation for negative coefficients in the larger and smallest size categories. The inconsistency is that farmers in larger and smallest size classes will increase their time away from farming as off-farm opportunities arise while farmers in the middle size classes are hypothesized to use "off-farm income to increase farm size . . ." (p. 295). We are not sure why farmer behavior changes just because farm income is a few thousand dollars different. More evidence on this hypothesis should be offered.

As hypothesized by MacMillan, Tung, and Tulloch, the signs on the age coefficients for all size classes should have been positive for ΔX_2 and negative for ΔX_3. However, both positive and negative statistically significant coefficients emerged for each variable. MacMillan, Tung, and Tulloch should have dealt with this problem in greater detail instead of just indicating that age is a complex variable. Perhaps the age variables should have not been included in the analysis because too much correlation exists between farm size and operator age. A look at the simple correlation matrix would have been valuable. It is our hypothesis that excessive correlation exists between the regressors and thus destroys the model's structural validity and weakens its predictive power.

In explaining the influence of capital stock, MacMillan, Tung, and Tulloch conclude that for small farm sizes an increase in capital stock leads to movement to larger farm size or exit from the industry. On the other hand, the positive coefficients on the size classes $10,000 through $25,000 "indicate the magnitude of the relationship between increasing capital investments and increasing farm numbers in the higher receipts classes . . ." (p. 296). No mention is made of the negative sign for the $25,000 and over class. The coefficient is significant and should be explained.

The dummy variables alternate in sign for the various size classes and are generally significant. In our opinion, it is insufficient to merely state "that unique provincial characteristics within the Prairie region affect changes in farm numbers . . ." (p.296). Some explanation as to why negative coefficients appear for the largest and smallest size classes and positive coefficients for the three other classes should be made. Likewise, a priori hypothesis regarding expected signs of the dummy variable coefficients should have been presented.

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Migration Analysis and Farm Number Projection Models: A Synthesis: Reply

J. A. MacMillan and F. L. Tung

Comments by Cleveland and Salkin are of the following nature: (*a*) the projection procedures are ambiguous because the conditions of the Markov theory are not met; (*b*) the projection results are "poor" and hence not useful; and (*c*) the regression analysis is criticized on both econometric and explanatory grounds. First, Cleveland and Salkin incorrectly interpreted the definitions of our model. Second, our paper outlines procedures for providing estimates of errors in farm number projection models in contrast to the omission of discussion of errors in previous projection results. The results indicate the potential of our model for reducing projection errors and hence are more useful than projection procedures currently being used in policy analysis that do not include error estimates. Third, the criticism of the econometric and explanatory power of the regression equations is trivial because the paper documents the preliminary nature of the results as a test of the model.

Cleveland and Salkin comment that $P_{11} = 1.0$ is required for consistency with the conditions of Markov theory. The theoretical model was modified by including the exit state to permit calculation of farmers leaving between census years. In 1961, there are no farmers in the exit state because they leave between 1961 and 1966. The same holds true for successive periods, and in all cases the first element of S_{t-1} is zero. The model does not permit exit from any class other than from S_2. Therefore, the probability of P_{11} is zero. The modifications are implied by the original definition of S_t as the vector of farm numbers in year $t - 1$ and by the definition of exit from farming as S_1. Farmers exiting cannot by definition appear in S_{t-1}.

Consistent with these modifications, the number of farmers leaving can be calculated directly from equation (1) of our previous paper (p. 293), contrary to Cleveland and Salkin's comment:

$$P'_0 S_{t-1} = \hat{S}_t. \tag{1}$$

The number leaving in 1961–66 (2,313) is calculated as the product of P_{21} and S_2, 1966 (0.1875 × 12,336), and this number is not used as an element of S_{t-1} in projecting the 1976 distribution of farmers. An improved wording for the footnote questioned by Cleveland and Salkin would change "previous census" to "previous census year."

The definitions in our paper clearly indicate that our model involved a modification of the Markov assumption. To achieve the strict consistency with Markov theory desired by Cleveland and Salkin, S_{t-1} has to be redefined to include the number of operators leaving between $t - 1$ and $t - 2$. The 1961–66 allocation would include the 5,895 farmers who left between 1956 and 1961. In 1961, the probability of 5,895 farmers leaving between 1956 and 1961 is 1.0. Cleveland and Salkin's derivation of $P_{11} = 1.0$ based on the assumptions underlying our model is incorrect.

If 1966 is taken as the starting point for the Markov process, the 1971 projection is obtained by including the 3,558 farmers who left between 1961 and 1966 as the first element of S_{t-1}. Calculations consistent with equation (1) result in the cumulation of the number of farmers leaving over the period 1961–71. Cleveland and Salkin's comment that "actual Manitoba projections for 'Leaving Agriculture' are 5,871, 7,374, and 8,351 for 1971, 1976, and 1981, respectively" is incorrect. The 5,871 figure for 1971 includes 3,558 farmers who left between 1961 and 1966. In modifications of the model that achieve strict consistency with Markov theory, the first element of S_t will show the cumulative number of farmers leaving.

The criticism of the usefulness of the projections is ambiguous. The opinion is based on the large errors in projections by income class. Federal Task Force on Agriculture (p. 261) and U.S. Department of Agriculture Economic Research Service agricultural economists (Daly, Dempsey, and Cobb, p. 322) have used similar projections without documenting attempts to measure either errors in projected farm numbers or farm numbers by income class.

The definition of ΔS_t as farmers and farm numbers is not inconsistent as Canadian farm numbers and farm operators are synonymous.[1] Comments on the explanatory power of the equations by Cleveland and Salkin and some previous reviewers of the paper illustrate a fundamental misunderstanding by many agricultural economists con-

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[1] The farm operator is defined by the census (Statistics Canada) as the person who is directly responsible for the agricultural operation of the holding, whether as owner, tenant, or hired manager. As only one operator is listed for each census farm, which is defined as a ranch or other agricultural holding of one acre or more with sales of agricultural products during the twelve-month period prior to the census of $50 or more, the number of operators is the same as the number of census farms.

cerning the role of economic theory and econometrics. Where theory is generally accepted to be supported by available evidence, such as negative price coefficients in demand equations, no explanation other than reference to theory is required (see Foote, p. 177; Rao and Miller, p. 35). In contrast, in analyses where theory and evidence have not provided an adequate foundation (such as migration theory) for specification of signs on variables, working hypotheses are required (see Ferber and Verdoon; Theil, p. 603). Evidence contrary to working hypotheses does not imply that the model lacks explanatory power. In fact, the absence of such contrary evidence would be suspect. The methodology used in the study and results correspond to the initial stages of model testing. As pointed out several times in the paper, further testing and refinements of hypotheses are required. Obvious tests noted in the paper include applying the refined model to other provinces and to 1966–71 data.

Perhaps the clarification will stimulate Cleveland and Salkin to refine the model and perform tests on Oklahoma data. For their information, the model was checked for multicollinearity (MacMillan, Tung, and Tulloch, p. 295). The independent variables' simple correlation matrix is

	ΔX_1	ΔX_2	ΔX_3	ΔX_4	D_1
ΔX_2	0.08				
ΔX_3	0.22	0.58			
ΔX_4	0.38	0.38	0.09		
D_1	0.03	0.30	0.03	0.45	
D_2	0.30	0.49	0.10	0.67	0.56.

It was not the intent of our paper to persuade agricultural economists, such as Cleveland and Salkin, that the preliminary results per se are useful. As stated in our conclusions (p. 297), the preliminary results support the potential usefulness of the model for overcoming deficiencies of common practices used in projecting farm numbers by receipts class for agricultural policy needs in Canada and the United States.

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A Neoclassical Analysis of the U.S. Farm Sector, 1948–1970: An Addendum

John Rosine and Peter Helmberger

The impacts of major exogenous forces on the U.S. farm sector over the period 1948–70 were quantified in a recent paper (Rosine and Helmberger). According to one of the assumptions in that analysis, direct payments were just sufficient to compensate farmers for land diversion. Further analysis has shown that this assumption is unreasonable in that estimated farm program benefits were less than direct payments in recent years. The entire analysis of the previous paper has been reworked in order to avoid this unreasonable assumption and its unwanted implications.[1] The new results are very consistent with the old except as regards the estimates of farm program benefits and costs. The newly estimated average annual farm program benefits to labor over the period 1960–70 amounted to $237.5 million. The corresponding estimate for land was $2,619.2 million. Benefits to land accounted for 91.7% of total benefits. Over the same period, average annual costs consisting of loss of consumer surplus plus government expenditures on farm income support was estimated at $5,192.4 million. The loss in economic efficiency averaged $2,335.5 million per year.

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[1] The previous analysis has been updated through 1972, revised in various ways, and expanded to include projection to 1985. The new findings will be reported in a forthcoming research report. The interested reader should write to the junior author in order to have his name placed on the mailing list.

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Publications

Books Reviewed

Oltmans, Willem L., ed. *On Growth*. N.Y.: Capricorn Books and G.P. Putnam's Sons, 1974, xii + 494 pp., $9.95.

An idea that will not die is that the wisdom of great minds is additive. The ancient king seeking counsel turned to his wise men and President Ford called eminent economists to a summit. The most imaginative instance is fictional: John Kendrick Bangs's assemblage of Blackstone, Confucius, Samuel Johnson, Shakespeare, and other shades on *A Houseboat on the Styx*.

Equally literary but emphatically nonfictional is Willem Oltmans's oral interview polling of seventy of the world's leading scholars for their opinions of the Club of Rome's *Limits to Growth*. Tape recorder in hand, the Dutch journalist crisscrossed the United States and Europe to pick the minds of personalities such as Arnold Toynbee, Marshall McLuhan, Barry Commoner, the Myrdals, Herbert Marcuse, Linus Pauling, and the chairman and founder of the Club of Rome, Aurelio Peccei.

The result is a chorus of opinionating, more dissonant than harmonizing but sprinkled with gems. Principal problem for the reader is to catalog seventy responses. The best recourse is to rank order them. Among sharpest critics of *Limits* are William Nordhaus, Carl Kaysen, Herman Kahn, and Paul Samuelson. Nordhaus declaims that "many competent independent analysts . . . conclude that the underlying assumptions are founded in pure fantasy" (p. 120). Of opposite persuasion and sharing the *Limits* apprehensions are Erza Mishan, Harrison Brown, Lester Brown, Claude Lévi-Strauss, and Paul Ehrlich—Ehrlich predictably, as he once was president of Zero Population Growth.

Many of the opinions are not calmly argued. In fact, the insights into personalities are hardly complimentary. Pedanticism and other sins of virtuosity show up. It remained for the anthropologist Lévi-Strauss, one of the more attractive persons, to sum the *Limits* technique simply:

> It should not be overlooked that what we have are models. *Limits to Growth* does not claim at all to represent what is taking place or what will take place. It is a model built in the laboratory, in order to better understand what is taking place in concrete reality. . . . It is the kind of procedure which we always follow in the social and human sciences. From this point of view I think that the character of the model, the result of the book, should be well understood. I am not at all impressed by [the] criticism. (P. 154)

If it be asked why other scholars cannot essay such refreshing balance, Lester Brown and Paul Ehrlich team to answer sharply. Says Brown, "The *Limits to Growth* is a threat to many people . . . to economists, for example, whose tool kits contain tools designed primarily to stimulate and encourage growth" (p. 370). Ehrlich believes men of achievement in science and government find their own success to confirm the soundness of the system: "The fact that these people are at the top . . . to them is the proof that the system has to be perfect, otherwise they would not have risen to the top" (p. 81).

Displayed in *On Growth* are a number of antagonisms not all closely related to *Limits*. Among favorite targets is the psychologist Skinner and his idea of managing the environment in order to manage man. Says Robert Lifton, "The notion of total planning and behavioral manipulation . . . lends itself to an authoritarian elite determining the plans for the rest of us. . . ." (pp. 148–49).

Some paired joustings appear, as between Commoner and Edward Goldsmith. Goldsmith snorts, "Barry Commoner is irresponsible" (p. 174).

A few themes come into view. One is skepticism regarding computerization in research. A second, arising from objection to the mechanistic quality of *Limits*, branches into the classic trilogy of the nature of man, his will, and his environment. Szent-Györgyi remarks, "Every problem has two solutions: a technical solution and an intellectual or moral solution" (p. 38). Delgado wants to create "a new kind of man" whom he calls "psychocivilized" (p. 258). Soleri, rather like Skinner, says that "in order to have a better person, you have to have a better environment" (p. 61), but Platt counters that better "world management" begins with "the sense of self-management" (p. 55). Thus are old debates rejoined.

Edwin Martin affirms soberly that "if man can find the political will and the political organization" he can resolve his problems. But he concedes his own uncertainty (p. 363).

The most impressive scholarship displayed is that not of the interviewees but of the interviewer. The author shows a deft comprehension of the work of each of the seventy scientists. The wisdom of learned men is not implicitly additive but it can be made so in the hands of a scholar-journalist such as Willem Oltmans.

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Wilcox, Walter W., Willard W. Cochrane, and Robert W. Herdt. *Economics of American Agriculture.* 3d ed. Englewood Cliffs: Prentice-Hall, 1974, viii + 504 pp., $14.95.

Wilcox, Cochrane, and Herdt attempt a monumental task as they try "to treat the agricultural sector of the economy in a comprehensive manner" (p. vii). Such a treatment requires, as a minimum, that the authors provide current, relevant information as well as historical information which describes and analyzes the entire dynamic agricultural sector. Further, a comprehensive text should define terms adequately and in a timely fashion, present material at a consistent level throughout the book, draw timely conclusions about current policy issues, and maintain a logical flow of concepts within and among chapters. Unfortunately, the overall effect is less than the cohesive whole implied by the above quotation.

Although this third edition has updated and reorganized information, this text follows the same basic order as the second edition. The brief description below depicts the content and flow of the six parts but does not cover all the ideas presented in the book.

Part 1 contains six chapters with the first describing the structure of American agriculture. Chapters 2–6 examine regional specialization, enterprise combinations on individual farms, resource combinations for an individual enterprise with emphasis on profit maximization and advances in farm technology, and aggregate supply.

Three of the four chapters of part 2 describe the marketing of farm products by flows, classes of markets, marketing functions, structural changes at the farm through retail levels, and changes in marketing services and costs. Consumer demand is the final topic of this section.

Part 3 (four chapters) discusses the price-income structure of agriculture. Topics include the determination of prices in purely competitive and imperfectly competitive markets, the income-producing (using) roles and problems of farm prices, and the resource allocation roles and problems of farm prices.

Part 4 relates farmers to national and international economies. Three chapters treat business fluctuations, agricultural trade, and the effects of advances in farm technology on aggregate supply and demand.

Part 5 focuses on agricultural resources. Five chapters cover human, land, water, purchased input, and credit resources of agriculture and consequences of environmental controls, taxation, and social control of land on resource use.

Part 6 devotes all three chapters to agricultural policy. The topics in this section are the history of governmental involvement in agriculture, policies to reduce risk and uncertainty in agriculture, and future farm policy alternatives.

The following impressions are offered about the book. These comments are based in part on experience gained from requiring this text for a course; they are not in any particular order.

Tables and U.S. Department of Agriculture charts used in the book provide information (basically) up to 1970. This information omits the tumultuous input and output market conditions of more recent years. Simplified captions used on some tables provide incomplete descriptions of their contents. The clarity of tables is further reduced by minimal use of cross rules to separate subcaptions and columns and to identify the units of measurement associated with columns.

Considerable effort is needed by the instructor to supplement the book (which, on the positive side, may justify the instructor's existence). Tables and charts need updating and clarifying; also complementary regional and state information should be provided to students.

The text frequently omits definitions of important terms and includes unnecessary definitions of less important terms. Definitions often appear after terms have been used and in a few instances are not positively supported by discussion or examples. A glossary might be a useful addition to the book.

The level of presentation changes considerably throughout the book. For example, an elementary description of specialization of production by region (chap. 3) builds to a subtly difficult discussion on aggregate supply (chap. 6). The authors do not state that they presume any previous knowledge of economics by the reader nor do they suggest chapter sequences to assist a student who is not familiar with agriculture.

The book persistently repeats the consequences of technological advances in farming. The discussions about these energy-consuming technologies are dated as a result of present world prices for energy. Current international liquidity problems are, of course, not discussed in the text.

The section concerning agricultural resources (part 5) seems disjointed. For example, the first section of chapter 20 about industrially produced inputs for farming is followed abruptly by a section on credit. Also, discussions about land as a resource are spread over more than one chapter. This section requires considerable supplementary material for classroom use.

I have two specific criticisms: imperfect competition receives a less than complete treatment (chap. 12), and the three stages of production are not mentioned in the discussion of production functions (chap. 4).

Instructors should weigh thoughtfully the net benefits of adopting a wideranging, traditional text like *Economics of American Agriculture.* It might be more effective to assign readings from a general theory text to support articles, bulletins, concept modules, and other material brought into the classroom.

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Scandizzo, Pasquale Lucio. *Il Mercato Dell'Olio Di Oliva*. Salerno, Italy: Camera Di Commercio Industria, 1974, xi + 92 pp., price unknown.

Sellekaerts, Willy, ed. *Economic Development and Planning—Essays in Honor of Jan Tinbergen*. White Plains, N.Y.: International Arts and Sciences Press, 1974, xxiv + 266 pp., $20.00.

Sommer, Ulrich. *Agrarwirtschaft*. Hannover, Germany: Alfred Strothe Verlag, 1974, vii + 241 pp., price unknown.

Tannenbaum, Steven R., Bruce R. Stillings, and Nevin S. Scrimshaw, eds. *The Economics, Marketing, and Technology of Fish Protein Concentrate*. Cambridge: MIT Press, 1974, x + 500 pp., $20.00.

Uselton, Gene C. *Lags in the Effects of Monetary Policy: A Nonparametric Analysis*. N.Y.: Marcel Dekker, 1974, xii + 174 pp., $12.75.

Van Brabant, Jozef M. P. *Essays on Planning, Trade and Integration in Eastern Europe*. Portland, Oreg.: International Scholarly Book Services, 1974, ix + 310 pp., $24.00.

News

Announcements

Annual Meeting, 1975

The annual meeting of the AAEA will be held at Ohio State University, August 10–13, 1975. Francis B. McCormick is chairman of local arrangements. The president has sent all AAEA members a letter concerning the details of the program. Further program information will be included in mailings from the local arrangements committee. Those who wish to submit a contributed paper should immediately contact the chairman of the Contributed Papers Sessions: Fred R. Taylor, Department of Agricultural Economics, North Dakota State University, Fargo, North Dakota 58102; telephone: (701) 237-7441. Abstracts of the papers will be published in the December Proceedings issue of the *Journal*.

Allied Social Science Associations Meeting, 1975

The winter meeting of the AAEA in cooperation with the Allied Social Science Associations will be held in Dallas, December 28–30, 1975. The employment center will start operating on December 27. These dates are changes from the October dates mentioned in earlier announcements.

Page Charge

The Board of Directors of the AAEA has instituted a page charge for the *Journal* effective with the August 1975 issue. All published contributions, with certain exemptions, will be subject to a charge of $40 per printed page payable by the author's supporting institution. Further information is available on the inside of the back cover.

Cover Letter

Some additional information is now required in the cover letters which accompany manuscript submissions to the *Journal*. The editor strongly encourages all prospective authors to read the instructions for writing such letters as well as the general instructions for the submission of manuscripts, both of which appear on the inside of the back cover.

National Employment Registry

A National Employment Registry for Agricultural Economists has been established to provide a central, nationwide clearinghouse for agricultural economists and employers.

The Registry maintains a listing of new and experienced professionals (*a*) who are seeking their first job assignment or a change in a long-term assignment or (*b*) who hold a long-term appointment but are willing to accept a temporary assignment with another employer such as a consultantship, visiting professorship, foreign assignment, etc.

This computer-based service provides rapid, efficient matching of candidates' qualifications with employers' specifications. No registration, referral, or placement fees are charged for this service.

Employment services are available year-round through the Registry office. In addition, service will be provided at the 1975 AAEA annual meeting. Job applicants should be registered with the Chicago office by June 10 to assure their resumes will be received by employers prior to the meeting. Employers should list their job vacancies by July 11 to assure receipt of candidate resumes before the meeting.

Registration forms may be obtained from: National Employment Registry for Agricultural Economists, 40 West Adams Street, Chicago, Illinois 60603; telephone: (312) 793-4866.

New School

A School of Renewable Natural Resources has been established in the College of Agriculture, University of Arizona, Tucson. David B. Thorud is director.

AAEA Committee Structure, 1974–75

Audit

James E. Criswell, Chairman, University of Kentucky, 1970
Larry D. Jones, University of Kentucky, 1974

Awards

Paul L. Kelley, General Chairman, Kansas State University, 1974

Distinguished extension programs:

Gordon D. Rose, Chairman, University of Minnesota, 1972

H. Doss Brodnax, Mississippi State University, 1974
George A. Ecker, University of Connecticut, 1974
John Holt, University of Florida, 1973
Verne W. House, Montana State University, 1974
H. C. Lampe, University of Rhode Island, 1972
William V. Neely, Extension Service, USDA, 1973
Everett Peterson, University of Nebraska, 1974

Distinguished undergraduate teaching:

Russell F. McDonald, Chairman, Texas A&M University, 1972
Hoy F. Carman, University of California, Davis, 1973
W. David Downey, Purdue University, 1972
Brad Gungoll, Oklahoma State University, 1973 (student)
Billy V. Lessley, University of Maryland, 1974
Richard W. Schermerhorn, University of Idaho, 1974
Robert O. Sinclair, University of Vermont, 1973
R. G. F. Spitze, University of Illinois, 1973

Outstanding master's program:

Joseph Havlicek, Jr., Chairman, Virginia Polytechnic Institute and State University, 1973
Johannes Delphendahl, University of Maine, 1972
C. Dirck Ditwiler, Washington State University, 1973
William D. Gorman, New Mexico State University, 1974
Roger G. Johnson, North Dakota State University, 1972
Jerry M. Law, Louisiana State University, 1973
Dale J. Menkhaus, University of Wyoming, 1974
J. B. Penn, Economic Research Service, USDA, Raleigh, North Carolina, 1974
Travis D. Phillip, Mississippi State University, 1974
Robert Raunikar, University of Georgia, Experiment, 1973
John R. Schaub, Economic Research Service, USDA, 1973
Robert N. Shulstad, University of Arkansas, 1974
Heinz Spielmann, University of Hawaii and Economic Research Service, USDA, 1974

Outstanding doctoral program:

Kenneth M. Duft, Chairman, Washington State University, 1972
David M. Bell, Economic Research Service, USDA, 1973
Rachel Dardis, University of Maryland, 1972
Buddy L. Dillman, Clemson University, 1973
Bernard L. Erven, Ohio State University, 1972
Charles R. Handy, Economic Research Service, USDA, 1973
Douglas D. Hedley, Agriculture Canada, 1973
Abbas Mirakhor, University of Alabama, Huntsville, 1974

Earl J. Partenheimer, Pennsylvania State University, 1973
Gordon C. Rausser, Iowa State University, 1974
C. Richard Shumway, Texas A&M University, 1974
L. Orlo Sorenson, Kansas State University, 1973
Forrest E. Walters, Colorado State University, 1973

Publications, quality of research discovery:

Gene L. Swackhamer, Chairman, Farm Credit Administration, 1972
A. Gordon Ball, University of Guelph, 1974
Bruce W. Cone, Battelle Northwest, 1974
William D. Dobson, University of Wisconsin, 1973
Burton L. French, Economic Research Service, USDA, 1973
Stanley R. Johnson, University of Missouri, 1973
Shlomo Reutlinger, International Bank for Reconstruction and Development, 1972
Andrew Vanvig, University of Wyoming, 1973
Richard G. Walsh, Colorado State University, 1972

Publications, quality of communication:

Gene L. Swackhamer, Chairman, Farm Credit Administration, 1972
Jack H. Armstrong, Farmer Cooperative Service, USDA, 1973
George L. Capel, North Carolina State University, 1972
Roger W. Fox, University of Arizona, 1973
Dennis R. Henderson, Ohio State University, 1973
Ralph G. Kline, Virginia Polytechnic Institute and State University, 1972
Wayne D. Rasmussen, Economic Research Service, USDA, 1973
Mary E. Templeton, West Virginia University, 1973

Publications of enduring quality:

Earl R. Swanson, Chairman, University of Illinois, 1973
D. Lee Bawden, University of Wisconsin, 1973
Dale C. Dahl, University of Minnesota, 1974
Vernon R. Eidman, Oklahoma State University, 1973
Robert S. Firch, University of Arizona, 1973
Thomas F. Hady, Economic Research Service, USDA, 1973
Allen B. Paul, Economic Research Service, USDA, 1973
Alan Randall, University of Kentucky, 1974
Ronald A. Schrimper, North Carolina State University, 1973

Nomination of agricultural economist for the Edward W. Browning Award of the American Society of Agronomy:

Lowell S. Hardin, Chairman, Ford Foundation, 1973

Willard W. Cochrane, University of Minnesota, 1973
Gordon A. King, University of California, Davis, 1973
Nathan M. Koffsky, World Bank, 1973

Bibliographical-Retrospective Search

J. Edwin Faris, Chairman, Clemson University, 1970
Allan S. Johnson, Economic Research Service, USDA, 1973
Marvin G. Julius, Iowa State University, 1974
Richard C. McArdle, Economic Research Service, USDA, 1973
Ivan W. Schmedemann, Texas A&M University, 1970
John T. Scott, University of Illinois, 1972
R. C. Smith, University of Delaware, 1974

Bibliographical-Retrospective Research Review

B. Delworth Gardner, Chairman, Utah State University, 1974
Linley E. Juers, Economic Research Service, USDA, Fort Collins, Colorado, 1974
William L. Park, Rutgers University, 1974
V. James Rhodes, University of Missouri, 1974

Contributed Papers, 1975 Annual Meeting

Fred R. Taylor, Chairman, North Dakota State University

Council for Agricultural Science and Technology, Review of AAEA Affiliation

G. E. Brandow, Chairman, Pennsylvania State University, 1974
Emery N. Castle, Oregon State University, 1974
W. D. Toussaint, North Carolina State University, 1974

Economic Statistics

R. James Hildreth, Chairman, Farm Foundation, 1969
W. Keith Bryant, Cornell University, 1974
Harry C. Trelogan, Statistical Reporting Service, USDA, 1970
Luther G. Tweeten, Oklahoma State University, 1974
Quentin M. West, Economic Research Service, USDA, 1972
Gaylord E. Worden, Economic Research Service, USDA, 1974

Employment Services

Loys L. Mather, Chairman, University of Kentucky, 1968
Joseph Ackerman, National Employment Registry for Agricultural Economists, 1973
Raymond R. Beneke, Iowa State University, 1974
Carleton C. Dennis, Agway, Inc., 1972
G. T. Dowdy, Tuskegee Institute, 1974
Stephen B. Harsh, Michigan State University, 1973
Dale E. Hathaway, Ford Foundation, 1971
Melvin R. Janssen, Economic Research Service, USDA, 1969

Extension Affairs

Charles Beer, Chairman, Extension Service, USDA, 1973
William M. Carroll, Pennsylvania State University, 1972
George L. Casler, Cornell University, 1972
Charles D. Covey, University of Florida, 1973
Lenard R. Kyle, Michigan State University, 1974
Robert C. Matthes, Kentucky Fried Chicken Corporation, 1974
Charles H. Rust, Montana State University, 1974

Fellows Election

Glenn L. Johnson, Chairman, Michigan State University, 1970
Karl A. Fox, Iowa State University, 1972
Don Paarlberg, USDA, 1971
Vernon W. Ruttan, Agricultural Development Council, 1974
Lauren K. Soth, *Des Moines Register and Tribune*, 1973

Finance

B. F. Stanton, Chairman, Cornell University, 1974
David H. Boyne, Ohio State University, 1974
Kenneth R. Farrell, Economic Research Service, USDA, 1974
John C. Redman, University of Kentucky, 1974

Handbook-Directory

Howard F. Robinson, Chairman, North Carolina A&T State University, 1974
Joseph Ackerman, National Employment Registry for Agricultural Economists, 1974
Emanuel Melichar, Federal Reserve System, 1974
John C. Redman, University of Kentucky, 1974

Industry Advisory

Bernard L. Sanders, Chairman, Farmland Industries, 1973
Ronald O. Aines, International Harvester Company, 1973
Eugene E. Gerke, Super Market Institute, 1974
Glenn H. Glover, Gold Kist, 1974
W. Bernard Lester, Florida Citrus Commission, 1973
Ted Rice, Continental Grain Company, 1973

Gene D. Sullivan, Federal Reserve Bank, Atlanta, 1973
Arthur G. Wilson, Canada Grains Council, 1974

Institutional Membership

Charles E. Erickson, Chairman, Cargill, Inc., 1974
Paul A. Baumgart, Safeway Stores, 1974
Dale E. Butz, Illinois Agricultural Association, 1973
Dan A. Klingenberg, Chase Manhattan Bank, 1974
Jimmye S. Hillman, University of Arizona, 1974
Dean E. McKee, Deere and Company, 1973

International

Norman R. Collins, Chairman, Ford Foundation, 1972
Clive R. Harston, Texas A&M University, 1972
J. Price Gittinger, International Bank for Reconstruction and Development, 1973
James P. Houck, Jr., University of Minnesota, 1973
Orlin J. Scoville, Kansas State University, 1972
Wayne W. Sharp, Foreign Agricultural Service, USDA, 1973
C. Peter Timmer, Stanford University, 1974
Abraham M. Weisblat, Agricultural Development Council, 1973

Investment

John C. Redman, Chairman, University of Kentucky, 1970
Dale E. Butz, Illinois Agricultural Association, 1970

Local Arrangements

AAEA Representative to Allied Social Science Associations Winter Meetings, 1974;
Robert V. Enochian, Economic Research Service, USDA, Albany, California

Annual Meeting, 1975:
Francis B. McCormick, Chairman, Ohio State University

Membership

John E. Lee, Jr., Chairman, Economic Research Service, USDA, 1972
David Y. Chen, North Carolina A&T State University, 1974
William E. Martin, University of Arizona, 1974
Ted R. Nelson, Oklahoma State University, 1973
John C. Redman, University of Kentucky, 1970
Fred O. Sargent, University of Vermont, 1974
Ed Williams, Massey-Ferguson, 1974

Nominating

Kenneth R. Tefertiller, Chairman, University of Florida, 1974
John O. Early, University of Idaho, 1974
W. E. Hamilton, American Farm Bureau Federation, 1974
Fred K. Hines, Economic Research Service, USDA, 1974
Sylvia Lane, University of California, Davis, 1974
Daniel I. Padberg, Cornell University, 1974
Joseph H. Yeager, Auburn University, 1974

Postwar Literature Review

Lee R. Martin, Chairman, University of Minnesota, 1967
John P. Doll, University of Missouri, 1968
Peter G. Helmberger, University of Wisconsin, 1969
Glenn L. Johnson, Michigan State University, 1967
Maurice M. Kelso, University of Arizona (retired), 1967
J. Patrick Madden, Pennsylvania State University, 1969
Edward W. Tyrchniewicz, University of Manitoba, 1969
M. L. Upchurch, University of Florida, 1967

Publication of Postwar Literature Review

Emerson M. Babb, Chairman, Purdue University, 1974
J. Patrick Madden, Pennsylvania State University, 1974
John C. Redman, University of Kentucky, 1974

Publications Policy Review

Chester B. Baker, Chairman, University of Illinois, 1974
Glenn E. Heitz, Federal Land Bank, St. Louis, 1974
William C. Motes, Economic Research Service, USDA, 1974

Resident Instruction

Wayne D. Purcell, Chairman, Oklahoma State University, 1973
Charles E. Erickson, Cargill Inc., 1973
Glenn C. Himes, Ohio State University, 1974
Lonnie L. Jones, Texas A&M University, 1973
James G. Kendrick, University of Nebraska, 1973
Jay Townsend, Purdue University, 1974 (student)
Walter J. Wills, Southern Illinois University, 1974

Tellers

A. Frank Bordeaux, Jr., Chairman, University of Kentucky, 1973
Harry H. Hall, University of Kentucky, 1973

Visiting Lecturer

R. James Hildreth, Chairman, Farm Foundation, 1969
William Herr, Southern Illinois University, 1973
James S. Wehrly, Western Illinois University, 1974
T. T. Williams, Southern University, 1973

AAEA Representative to the Agricultural Development Council Research and Training Network Program

Norman R. Collins, Ford Foundation

AAEA Representative to the American Society of Agronomy

C. Ray Hoglund, Michigan State University (retired)

American Statistical Association, AAEA Joint Advisory Committee on Agricultural Statistics

R. James Hildreth, Farm Foundation
George G. Judge, University of Illinois
Dean E. McKee, Deere and Company

AAEA Representative to the Bureau of Census Advisory Committee on Agricultural Statistics

M. L. Upchurch, University of Florida

AAEA Representative to Federal Statistics Users Conference

Norman M. Coats, Ralston Purina Company

AAEA Representative to the National Bureau of Economic Research

Harold G. Halcrow, University of Illinois

AAEA Representative to the National Research Council

John C. Redman, University of Kentucky

U.S. Council of the International Association of Agricultural Economists

M. L. Upchurch, Chairman, University of Florida
Norman R. Collins, Program Advisor, Ford Foundation
Max Myers, South Dakota State University
Lyle P. Schertz, Economic Research Service, USDA

Personnel

Agricultural Development Council

Appointments: William M. Bateson is a visiting professor at the Center for Economic Development Administration in Katmandu, Nepal; **Edward J. Clay** is an associate at the Bangladesh Agricultural Research Council in Dacca.

University of Arizona

Return: John C. Day is back from Ankara, Turkey where he spent eighteen months in the Ministry of Agriculture involved in agricultural planning and development.

Clemson University

Appointment: Russell W. Sutton, Ph.D. University of Kentucky, is an assistant professor.

Colorado State University

Return: Jerry B. Eckert will be back in fall 1975 after a three-year assignment with the Agency for International Development in Pakistan.

Cornell University

Appointments: Ernesto C. Lucas, associate professor at Southern University, is the recipient of a National Science Foundation Faculty Fellowship and is a visiting research fellow in spring 1975; **Robert Milligan,** Ph.D. University of California, Davis, is an assistant professor.
Honor: Howard Conklin, professor, received an award for "Distinguished Service to the Agriculture of the Empire State" from the New York Farm Bureau.

University of Guelph

Appointment: Elmer L. Menzie is a professor and the director of the School of Agricultural Economics and Extension Education, effective July 1, 1975.

University of Hawaii

Appointment: Samuel G. Camp III is an assistant agricultural economist for 1974-75.

CED: Commodity Economics Division of ERS; **EDD:** Economic Development Division of ERS; **ERS:** Economic Research Service of USDA; **FDD:** Foreign Development Division of ERS; **NEAD:** National Economic Analysis Division of ERS; **NRED:** Natural Resource Economic Division of ERS.

University of Illinois

Appointment: Thomas E. Elam is an assistant professor.

Iowa State University

Appointments: Thomas P. Drinka, Francis Lea Kaiser, Richard A. Levins, Treena K. Levins, and **Craig W. O'Riley** are research associates.
Honor: Earl O. Heady, Curtiss Distinguished Professor and director of the Center for Agricultural and Rural Development, received the 1974 Gamma Sigma Delta International Award for Distinguished Service to Agriculture.

Kansas State University

Appointment: Stanley W. Bratcher, M.S. Kansas State University, is an area extension economist in farm management at Hutchinson, Kansas.

University of Massachusetts

Appointment: Gene McMurtry, former director of Community Resource Development, Extension Division, Virginia Polytechnic Institute and State University, is the director of the Extension Division.

Michigan State University

Appointment: Stanley R. Thompson, at work on a Ph.D. at Cornell University, is an assistant professor in commodity market analysis.

University of Minnesota

Appointments: Nasser A. Aulaqi, Ph.D. University of Nebraska, and **Jeremiah E. Fruin,** Ph.D. University of California, Berkeley, are research associates.

Mississippi State University

Appointment: Stanley Rosenberger, former professor and marketing specialist at the University of Florida, is with the Food and Fiber Center.
Reassignment: Chester M. Wells, professor, is the interim head of the Editorial Department of the Mississippi Agricultural and Forestry Experiment Station.

University of Missouri

Appointments: Richard P. Kesler, associate professor at the University of Illinois, is a visiting as-

sociate professor; **James B. Kliebenstein,** former assistant professor at Northwest Missouri State University, is an assistant professor in farm management.

University of Nebraska

Honor: Philip Henderson received an award of merit from Gamma Sigma Delta Fraternity.

North Dakota State University

Appointment: Donald F. Scott, Ph.D. University of Missouri, is an assistant professor.

Ohio State University

Retirement: John H. Sitterley has left after forty-six years of service.

Oklahoma State University

Appointment: Raleigh A. Jobes, formerly at Clemson University, is an assistant professor and extension economist in farm management.

Oregon State University

Appointments: David E. Ervin, Ph.D. Oregon State University, is a research associate; **Katar Singh,** Ph.D. University of Illinois on leave from G. B. Pant University in India, is a visiting associate professor.

Pennsylvania State University

Appointment: John W. Malone, formerly at the University of Nevada, is a professor and head of the Department of Agricultural Economics and Rural Sociology.

University of Puerto Rico

Appointment: Robert M. Finley, on leave from the University of Missouri, is a visiting professor.

Purdue University

Resignation: Valerie Justice has returned to London.
Honor: Bobby Keen is the international director of Farmhouse Fraternity, 1974–75.

U.S. Department of Agriculture

Appointments: Russell L. Hawes, formerly with the General Services Administration, is the assistant to the director of the Agricultural Marketing Service; **Gene F. Miller,** Ph.D. University of Missouri, is a team leader in El Salvador under a USDA-Agency for International Development Participating Agency Service Agreement; **Ronald L. Tinnermier,** on leave from Colorado State University, is with the Technical Assistance Bureau, USDA-Agency for International Development; **Gaylord E. Worden,** formerly with NEAD, is the automatic data processing coordinator for ERS.
Appointments in CED: Gary A. Frank, Ph.D. University of Wisconsin, is with the Dairy Program Area; **Frederick Gray,** formerly with NEAD.
Appointments in NRED: Paul Dyke is at Oregon State University; **James Jacobs** is at Cornell University; **Douglas Lewis; Richard Magleby,** formerly with FDD; **Clayton W. Ogg,** Ph.D. University of Minnesota, is in Upper Darby, Pennsylvania; **Chester (Ed) Young** is at Pennsylvania State University.
Reassignments: Rex F. Daly, back after a two-year assignment in Bangkok, is a senior economist in the Office of the Administrator, ERS; **George H. Goldsborough,** former director of the Federal-State Marketing Improvement Program of the Agricultural Marketing Service, is the deputy director of the Agricultural Marketing Service; **William E. Kibler,** former director of the Survey Division, is the statistician in charge of the Raleigh, North Carolina State Statistical Office of the Statistical Reporting Service; **Christian A. Stokstad,** former chief of the Prices and Labor Branch, is the director of the Survey Division of the Statistical Reporting Service.
Reassignments in CED: Thomas W. Little, formerly at Virginia Polytechnic Institute and State University, is in Washington, D.C; **James L. Pearson,** formerly at the University of Florida, is the deputy director of CED in Washington, D.C.
Reassignments in EDD: Melvin R. Janssen, assistant director of EDD, is serving as principal agricultural economist of the Cooperative State Research Service until June 1975; **Joseph Schmidt,** formerly in Washington, D.C., is at Oklahoma State University working on the improvement of rural land development throughout the Great Plains area.
Reassignment in NRED: Virgil Whetzel, formerly in Morgantown, West Virginia, is at Colorado State University.
Resignations in CED: Charles O. Dell; Jimmy L. Matthews is with the Treasury Department; **Gerald O'Mara** is with the Office Price Administrator.
Resignation in EDD: Robert C. McElray, former leader of Manpower Studies, is with the Employment Standards Administration in the Department of Labor.
Resignations in NRED: Dudley Mattson is with the Environmental Protection Agency; **Robert Oehlachlaeger.**

Retirements: Robert B. Glasgan has left EDD after thirty-six years of federal service; **Russell P. Handy,** former statistician in charge of the Raleigh, North Carolina State Statistical Office, has left the Statistical Reporting Service; **J. Gwyn Sutherland.**
Honor: Floyd F. Hedlund received the USDA's Distinguished Service Award from Secretary Butz at last May's Annual Awards Ceremony.

Virginia Polytechnic Institute and State University

Appointments: James E. Pratt, M.S. Purdue University, is a research associate; **C. P. Steve Tsang,** Ph.D. Virginia Polytechnic Institute and State University, is an acting assistant professor; **Joel S. Williams,** Ph.D. University of Florida, is an assistant professor.

University of Wisconsin

Appointment: Tom Clavenger from New Mexico State University is an honorary fellow in market organization and coordination during January–June 1975; **Monroe Rosner** and **Steven Smith** are working on Wisconsin's Title V program; **Larry Salathe** is a research associate working on expenditure patterns.
Returns: Hugh Cook is back as the head of the Department of Agricultural Economics after a two-year leave spent at the University of Ife in Western State Nigeria under a University of Wisconsin-Agency for International Development contract; **Marvin Miracle** is back conducting research on innovations in agriculture under a Ford Foundation grant after a one-year leave spent in the Central Province of Kenya.

Other Appointments

John A. Blaufuss, M.S. Purdue University, is with the Illinois Grain Corporation in Bloomington.
John L. Dillon, on leave from the University of New England, will be a visiting professor at the Universidade Federal do Ceará in Fortaleza, Brazil during 1975-76.
Donald B. Erickson, on leave from Kansas State University, is at the Economics Research Institute, Stockholm School of Economics during 1974–75.
Allen Grommet, Ph.D. Michigan State University, is a staff economist with the U.S. House of Representatives Budget Committee.
Samuel F. Hosken, M.S. Purdue University, is with the Dairy Institute Candido Tostes in Juiz de Fora, Brazil.
Julius Hummel, M.S. University of Missouri, is an associate transportation analyst with B. F. Goodrich in Cleveland.
Hisashi Ishiyama, M.S. Oregon State University, is with the Marketing Department of Dow Chemical International in Tokyo.
Jeung H. Lee, Ph.D. Michigan State University, is an associate professor at National Kyung Sang University in Chinju, Korea.
William Lin, formerly at the University of Washington, is a research economist with Oak Ridge National Laboratory in Oak Ridge, Tennessee.
Tridib K. Mukherjee, Ph.D. Appalachian State University, is a professor and team member of the Cameroon Project at Southern University.
George R. Perkins, former assistant professor at the University of Florida, is with the planning and analysis section of the Board of Regents in Tallahassee.
Randall Reeves, M.S. University of Missouri, is a credit analyst with the First City National Bank in Houston.
Marcelo Roguel, Ph.D. University of Wisconsin, is at Central Luzon State University in the Philippines.
Shyamal Roy, Ph.D. University of Missouri, is a research assistant for the Brookings Institution.
Kenneth Schneeberger, on leave from the University of Missouri, is at Tennessee State University.
Alan M. Strout, former council associate in Indonesia for the Agricultural Development Council, is with the Energy Laboratory at the Massachusetts Institute of Technology.
Walter Swenson, M.S. University of Missouri, is the export promotion manager for the Missouri Department of Agriculture.
Ron Thompson, Ph.D. Michigan State University, is an assistant professor at Virginia State College.
Carl Utterstrom, M.S. University of Missouri, is an economist with the National Swedish Dairy Association in Stockholm.
Robert E. Zellner, Ph.D. University of Missouri and former staff economist for Bell Canada, is director of economic research for Cook Industries.

Obituaries

Ellsworth W. Bell

Ellsworth W. Bell, 71, professor emeritus at the University of Massachusetts, died November 8, 1974.

Bell was born in Maplewood, Pennsylvania, February 24, 1903. He received a B.S. degree from Pennsylvania State College in 1926 and an M.S. degree from the University of Vermont in 1928.

He came to the University of Massachusetts in 1929 and taught economics for two years. In 1930, he joined the Extension Service at the University as an agricultural economist. During 1968 he taught at Hokkaido University in Sapporo, Japan.

Bell served on many agricultural committees in Massachusetts and the Northeast region in the fields of dairy, poultry, and livestock marketing.

Bell retired in 1969 after serving the Commonwealth of Massachusetts and the University for forty years.

He is survived by two sons, Hubert W. and Donald M., two daughters, Mrs. Leland Miner and Mrs. Joseph Bostjancic, two brothers, and ten grandchildren.

Mordecai Joseph Brill Ezekiel

Mordecai Ezekiel died in Washington, D.C. on October 31, 1974. He was one of the world's most widely recognized agricultural economists.

Ezekiel was born in Richmond, Virginia on May 10, 1899, of pre-Revolutionary, Portuguese-Jewish ancestry. He completed his B.S. degree in agronomy and general agriculture at the Maryland State College of Agriculture (now University of Maryland). While employed, he completed work for his M.S. at the University of Minnesota in 1923 and for his Ph.D. at the Brookings Institution of Washington in 1926. The University of Maryland conferred the honorary Doctor of Science degree in 1963. He was elected a Fellow of the American Agricultural Economics Association in 1958.

After graduating from the University of Maryland and serving in the U.S. Army for six months and in the Bureau of War Risk Insurance during part of 1919, he went to the Bureau of the Census. During his three years there, he worked on the 1920 Census of Agriculture.

In 1923, Ezekiel joined the Division of Farm Management of the new Bureau of Agricultural Economics and began the first of what were to become two distinctive careers in agricultural economics. While in the BAE, Ezekiel contributed notably to the development of statistical theory and techniques in price analysis, publishing his now classic *Methods of Correlation Analysis* in 1930. In his concerns for farm income, the economic analysis of supply-demand relations, and the surplus problem, he was applying his scholarly knowledge to major problems of the period. Ezekiel was one of the first lecturers in the USDA Graduate School, a relationship that was to continue for many years.

From February 1930 to March 1933, as assistant chief economist to the Federal Farm Board, Ezekiel advised the Board on its efforts to check the decline in the price of farm products. However, he realized that production controls were essential and incorporated this idea in the final report of the Board. He worked with Congressmen, farm leaders, and others in developing some of the approaches to the problem which he helped incorporate in the Agricultural Adjustment Act of 1933.

Ezekiel's first career in agricultural economics reached its peak in the years from 1933 to 1946, when he was economic advisor to the secretary of agriculture, a post established for him. He continued to make economic analyses, one of the most notable, with Louis Bean, being *The Economic Bases of the Agricultural Adjustment Act*. He developed a plan for ending poverty in America by guaranteeing a minimum income of $2,500 a year for each citizen. He foresaw the Supreme Court decision invalidating the Agricultural Adjustment Act and had proposals for substitutes at hand. His ideas in this and other farm areas and his skill in getting his ideas into legislation contributed greatly to New Deal agricultural programs and their implementation.

In 1946, Ezekiel began his second career as an agricultural economist when he became a member of the first field mission of the FAO. He drafted the report of this mission to Greece. From 1947, when he became an economist in FAO, until 1962, when he retired after serving as assistant director general and special assistant to the director general, Ezekiel emphasized the need for a world food program and for technical agricultural assistance to developing nations. He urged the use of surplus farm products from the United States and other nations to finance economic development. During World War II, he had proposed a world "ever-normal granary," based upon experience in the USDA. He was a key advisor in the FAO, building for it a veritable international agricultural economics bureau.

In July 1962, Ezekiel returned to the United States, joining the staff of the Agency for International Development. For three years he was responsible for AID relations with the United Nations. In the two years before his retirement in 1967, he advised on AID policies concerning international agriculture.

Ezekiel had the opportunity, as few men have, to see many of his proposals become agricultural policies and programs of the United States and agricultural development programs of the United Nations.

Conrad H. Hammar

Conrad H. Hammar was born January 28, 1895 in Madison, Minnesota and died November 5, 1974 in St. Paul, Minnesota after a distinguished career in education, government service, and private business. He graduated from the University of Minnesota in 1924 and received the Ph.D. from there in 1930.

Hammar joined the agricultural economics faculty at the University of Missouri in 1929 and served there until the 1940s. He also taught for short periods at the University of Minnesota and at Cornell University. He served as a vice president of the American Farm Economic Association in 1943. His principal subject area was land economics.

He joined the Army in 1943 and served on General Eisenhower's staff for three years. In late 1946, he began service, as a civilian with a joint U.S., French, British, and Russian group, the Allied Control Authority, trying to solve food and agricultural problems in Germany. For his efforts, Dr. Hammar received a German citation. He is perhaps best remembered for his efforts to revive and reestablish agricultural colleges in Germany. In 1952, he went to Baghdad as chief agriculturalist for the Point Four Program.

After retiring from the foreign service in 1957, Dr. Hammar spent much of the rest of his life in business, as a consultant, and in writing two books. Most of his consulting involved land appraisal for the Indian Claims Commission. In recent years, ill health forced his retirement from professional activities, but he always remained very active with his garden work.

Charles Leslie Stewart

Charles Leslie Stewart, emeritus professor of agricultural economics at the University of Illinois, Urbana-Champaign, died September 1, 1974, after a long and fruitful professional career. He was one of the founders of agricultural economics on the Urbana campus and a contributor to its development for a span of thirty-five years. Born September 3, 1890, he graduated from Illinois Wesleyan University in 1911; he received his M.S. in 1912 and his Ph.D. in 1915, both from the University of Illinois.

As a national scholar, Stewart's best-known contribution was his conception and development in the 1920s of an export debenture plan, some features of which were later broadly adopted in federal price-support legislation. In 1920, he first received national recognition with the publication of his doctoral thesis, *Land Tenure in the United States with Special Reference to Illinois*. Following this he was included in *Who's Who in America* from 1920 to 1974. He published widely in land economics. In the 1958 *Yearbook of Agriculture,* it is stated that because of his contribution to land economics the volume would have been dedicated to him if it were the policy to give such recognition. In 1943 he was awarded an honorary Doctor of Science degree from Illinois Wesleyan University. In 1960, he was the recipient of an honorary award made by the Illinois Society of Professional Farm Managers and Rural Appraisers. In 1970, a final tribute to his lasting scholarship was the reprinting of his doctoral dissertation as a book, fifty years after its first national recognition.

As a community and intellectual leader, Stewart was the leading sponsor of the pension provision in the Illinois Constitution which is the foundation of the current Illinois state universities' retirement program, and after retirement he was active in promoting needed improvements in the program. He was a member of numerous professional associations and local service organizations.

He was loved and will be long revered by the members of a large, active family. He is survived by his wife, Ruth Want Stewart, two daughters, Mary Margaret Binfield, Hinsdale, Illinois, and Barbara McDonald, Arlington, Virginia, and one son, Charles L., Jr., Glencoe, Illinois. A second son, James Kinley, was killed in action in Germany in World War II. In addition, he is survived by thirteen grandchildren and five great-grandchildren.

Because of his boundless energy, keen intellect, and independence of thought, Charles L. Stewart symbolized a lifetime of professional service in research, teaching, and national policy making; and, because of his warmth as a human being and his great consideration for others as well as his contributions, he will be long remembered by his many friends and associates.

1974 Ph.D. Recipients in Agricultural Economics, by Subject Area

Categories

1. Agricultural economics, general
2. Agricultural finance, capital, and credit
3. Agricultural labor and rural manpower
4. Agricultural products: demand, supply, and prices
5. Cooperatives and cooperation
6. Economic development, growth, and planning
7. Environmental economics
8. Food and consumer economics
9. Human resource development
10. Institutions
11. Land tenure
12. Marketing and location
13. Natural resource economics
14. Production economics and management
15. Public policy and programs
16. Regional economics
17. Research methodology
18. Socioeconomic research
19. Technological change
20. Trade
21. Transportation

1. Agricultural Economics, General

E. N. K. I. Andah, B.A. Stanford University, 1962; M.A. Stanford University, 1964; Ph.D. University of Manitoba, "Cocoa Price Formation and the Prospects of Its Stabilization."
Daniel L. Landau, B.A. Hebrew University, 1970; Ph.D. University of Chicago, "The Business Cycle and Productivity Change."

2. Agricultural Finance, Capital, and Credit

Vinay Kumar Bhargava, B.S. Uttar Pradesh Agricultural University, 1966; M.S. Uttar Pradesh Agricultural University, 1968; Ph.D. University of Illinois, "Effect of Publicly Supported Credit Programs on Economic Growth of Small Farmers in District Budaun (India)."
Telford Roy Bogle, B.S. Pennsylvania State University, 1960; M.S. Ohio State University, 1968; M.S. Purdue University 1972; Ph.D. University of Missouri, "Farm Investment Analysis—Hand-Calculated Comparative Budgeting and Computerized Five-Year Transitional Budgeting."
Richard J. Edwards, B.S. Cornell University, 1961; M.S. Purdue University, 1966; Ph.D. Purdue University, "The Cost of Assessing Property in Indiana, Iowa and Wisconsin: 1963."
Soetatwo S. Hadiwigeno, B.S. Gadjah Mada University, 1959; M.S. University of Colorado, 1962; Ph.D. University of Illinois, "Potential Effects of Modifications in the Credit Program for Small Farms in East Java, Indonesia."
Charles Anthony Kraenzle, B.S. University of Missouri, 1964; M.S. University of Missouri, 1970; Ph.D. University of Connecticut, 1974, "An Economic Evaluation of Decision Strategies In The Disinvestment and Retirement Stages of Farming."
Stephen F. Matthews, B.S. University of Missouri, 1969; Ph.D. University of Missouri, "The Limited Partnership as an Investment Vehicle in Agriculture."
Joseph Charles Meisner, B.S. St. Louis University, 1950; M.B.A. Creighton University, 1965; M.A. Washington University, 1968; Ph.D. University of Missouri, "Investor Capital, Taxes and the Structure of Cattle Feeding."
Jerald LeGrand Nelson, B.A. University of Utah, 1967; M.E. North Carolina State University, 1969; Ph.D. North Carolina State University, "Taxation and Other Economic Effects on the Capital Structure of Farm Supply Cooperatives."
Musa Ahmad Samman, B.S. American University of Beirut, 1962; M.S. Stanford University, 1968; Ph.D. University of Missouri, "Analysis of Factors Influencing Loan Losses of Production Credit Associations."
Gurbachan Singh, B.S. Punjab University, 1965; M.S. Punjab University, 1958; Ph.D. Ohio State University, "Farm Level Determinants of Credit Allocation and Use in Southern Brazil, 1965–1969."
J. V. Venkataram, B.S. University of Madria, 1964; Ph.D. University of Illinois, "Financing Farm Innovations in Mandy District, Mysore, India."

3. Agricultural Labor and Rural Manpower

James Vincent Higgins, B. Agr. Sci. National University of Ireland, 1967; M.E. North Carolina State University, 1970; Ph.D. North Carolina State University, "An Analysis of Family Labor Supply in Rural Areas."
Wesley Neil Musser, B.S. University of Nebraska, 1967; M.S. University of Nebraska, 1968; Ph.D. University of California, Berkeley, "Federal Manpower Policy and the Rural Sector 1960–1971."
Shyamal Roy, B.A. University of Calcutta, 1965; M.A. University of Delhi, 1967; Ph.D. University of Missouri, "Effects of Farm Tractorization on Productivity and Labor Employment on Punjab Farms, India."
Peter Winthrop Wyeth, B.S. University of London, 1966; M.S. University of California, Berkeley,

1970; Ph.D. University of California, Berkeley, "An Economic Evaluation of Trade Union Power in California Agriculture."

4. Agricultural Products: Demand, Supply, and Prices

John L. Adrian, B.A.A. Auburn University, 1969; M.S. Auburn University, 1971; Ph.D. University of Tennessee, "Specification of the Effects of Income and Other Socioeconomic Factors on the Consumption of Food Nutrients."
William T. Boehm, B.S. University of Wisconsin, 1970; M.S. Purdue University, 1972; Ph.D. Purdue University, "An Econometric Analysis of the Household Demand for Major Dairy Products."
Joe T. Davis, B.S. University of Tennessee at Martin, 1968; M.S. University of Tennessee, 1972; Ph.D. University of Tennessee, "An Econometric Analysis of the Quarterly Demand and Supply Relationships for Feeder Cattle in the United States."
Muammer Dogan, A.Eg. University of Ankara, 1965; M.A. Pennsylvania State University, 1969; M.S. University of Wisconsin, 1972; Ph.D. University of Hawaii, "Tariff Feasibility and the Competitive Position of Hawaii Pineapple in the U. S. Market."
Hilarious William Fuchs, A.A. Union College, 1963; B.S. Rutgers University, 1966; M.S. Rutgers University, 1968; Ph.D. University of Connecticut, "An Intertemporal Activity Analysis Model of the United States Apple Industry."
Gene F. Miller, B.S. University of Missouri, 1957; M.S. University of Missouri, 1962; Ph.D. University of Missouri, "An Economic Analysis of Basic Grains in El Salvador."
James Elbert Nix, B.S. University of Georgia, 1965; M.S. University of Georgia, 1967; Ph.D. Clemson University, "Beef Production in the South: Model Development and Economic Appraisal of Beef Supply Response."
Ronald Roy Piggott, G.Ag.Ec. University of New England, 1966; M.Ag.Ec. University of New England, 1970; Ph.D. Cornell University, "A Farm Level Econometric Model of the U.S. Apple Industry: Application to Forecasting and Analyzing Policy Issues."
Alhambra Rachman, Ph.D. Montana State University, "An Econometric Analysis of the Demand for Beef in Japan."
Anthony James Reutens, B.A. University of Hong Kong, 1958; M.S. University of Illinois, 1972; Ph.D. University of Illinois, "An Econometric Analysis of the International Rubber Economy."
John Blair Riley, B.S. Virginia Polytechnic Institute and State University, 1969; M.S. Virginia Polytechnic Institute and State University, 1971; Ph.D. Oklahoma State University, "Equilibrium in the Fluid Milk Industry Under Alternative Pricing Policies and Structural Changes, 1972–1976."
Chia-Pang Steve Tsang, B.A. Taiwan Chung Hsing University, 1968; M.S. University of Nevada, 1971; Ph.D. Virginia Polytechnic Institute and State University, "An Economic Analysis of the Impact of Technology Change in Virginia's Tomato Processing Industry."
Douglas R. Williams, B.S. Utah State University, 1964; M.S. New Mexico State University; Ph.D. Louisiana State University, "Relationship of Fiber Test Data and Other Factors to Prices Paid for Cotton."

5. Cooperatives and Cooperation

Thomas V. Koszarek, B.S. University of Wisconsin, 1968; M.S. University of Wisconsin, 1969; Ph.D. University of Minnesota, "Market Performance of Minnesota Retail Farm Supply Cooperatives."

6. Economic Development, Growth, and Planning

Yiadom Atta-Konadu, B.A. University of Ghana, 1961; M.S. University of Manitoba, 1966; Ph.D. Michigan State University, "Economic Optima in Resource Allocation for Smallholder Subsistence Farming in Ghana."
Carlos Arturo Baanante, B.S. Universidad Agraria, 1962; M.S. North Carolina State University, 1966; Ph.D. North Carolina State University, "Andean Group Economic Integration: The Case of the Nitrogenous Fertilizer Industry."
Boyce Burton Balfour, II, B.S. Texas A&M University, 1966; M.S. Texas A&M University, 1967; Ph.D. North Carolina State University, "Spatial Planning and Analysis of the Location of Public School Facilities."
Roger Lee Baur, B.S. Michigan State University, 1966; M.S. Michigan State University, 1968; Ph.D. Ohio State University, "Historical Description of Capital and Technology Changes at the Farm Level in Four Southern Brazil Regions: 1960–1969."
Stephen Devon Biggs, B.Sc. University of London, 1963; M.S. University of Illinois, 1965; Ph.D. University of California, Berkeley, "Multi-Sector Model for the Agricultural Socio-Economic System: Purnea District, Bihar, India."
Arthur Lee Coffing, B.S. North Dakota State University, 1963; M.S. University of Idaho, 1965; Ph.D. Iowa State University, "PL-480 Imports, the Disincentive Effect, and Implications for Development in Turkey."
Gunars Dambe, B.S. Iowa State University, 1963; M.S. Iowa State University, 1968; Ph.D. Iowa State University, "Planning for More Labor Intensive and More Productive Agriculture in Colombia."
Aaron Dehter, Ph.D. University of Minnesota, "Economic Analysis of an Urban Center as a Potential Growth Pole: An Argentine Case."

Walter Graeme Donovan, B.Agr.Sci. University of Canterbury, 1964; M.Agr.Sci. University of Canterbury, 1967; Ph.D. Cornell University, "Employment Generation in Agriculture: A Study in Mandya District, South India."

Yakub Fabiyi, B.Sc. University of Ife, Nigeria; M.S. University of Wisconsin; Ph.D. University of Wisconsin, "Land Tenure Innovations in Rural Development: The Problems in Western Nigeria with some Tanzanian Comparisons."

James Black Fitch, B.S. Stanford University, 1961; M.S. Purdue University, 1970; A.M. Stanford University, 1972; Ph.D. Stanford University, "Economic Development in a Minority Enclave: the Case of the Yakima Indian Nation, Washington."

Shigemochi Hirashima, B.A. Osaka University, 1960; M.S. Cornell University, 1968; Ph.D. Cornell University, "Interaction Between Institutions and Technology in Developing Agriculture—A Case Study of the Disparity Problems in Pakistan Agriculture."

Tim David Johnston, B.S. Central Michigan University, 1965; M.S. Iowa State University, 1971; Ph.D. Iowa State University, "Income Potential of Small Farms in Guatemala."

Christos Kamenidis, B.S. University of Thessaloniki, 1963; M.S. University of Missouri, 1971; M.A. Michigan State University, 1974; Ph.D. Michigan State University, "Efficient Organization of the Livestock Meat Marketing System in Eastern Macedonia, Greece."

Ying-Nan Lin, B.S. Taiwan Provincial Chung-Hsing University, 1958; Ph.D. University of Tennessee, "Rural Development Analysis: Direction Identification, Measurement and Interpretation for Public Policy Purpose applied to Four Tennessee Counties."

Robert Jackson Martin, B.S. Mississippi State University, 1964; M.S. Mississippi State University, 1966; Ph.D. Virginia Polytechnic Institute and State University, "Economic Development Potentials From Sector Demand Projections and Simulated Industry Alternatives, Eastern Shore, Virginia."

Roger Dee Montgomery, B.A. Wesleyan University, 1964; M.S. Cornell University, 1971; Ph.D. Cornell University, "The Link Between Trade and Labor Absorption in Rural Java: An Input-Output Study of Jogjakarta."

Hidajat Nataatmadja, Sardjana Pertanian, Bogor Agricultural University, Indonesia, 1962; Ph.D. University of Hawaii, "Factors Affecting Adoption of Improved Farm Practices by Rice Farmers in Indramayu, Indonesia."

James Ralph Nelson, B.S. Texas Tech University, 1966; M.S. Texas Tech University, 1968; Ph.D. Oklahoma State University, "Systems Simulation of Public Policy Strategies for Multicounty District Economic Development."

Oladejo Ogunronbi, B.Sc. University of Ife, Nigeria; M.S. University of Wisconsin; Ph.D. University of Wisconsin, "Agricultural Credit, Peasant Agriculture and Economic Development: Insights and Implications for Western Nigeria."

Neil A. Patrick, B.S. Iowa State University, 1963; M.S. Iowa State University, 1967; Ph.D. Iowa State University, "Development and Application of a Model for Multi-country Rural Community Development."

Barry Michael Popkin, B.S. University of Wisconsin, 1967; M.S. University of Wisconsin, 1969; Ph.D. Cornell University, "Vitamin A Deficiency in the Philippines: The Development and Analysis of Alternate Interventions."

Alvaro Posada, B.S. Facultad de Agronomia, 1951; M.S. Michigan State University, 1954; Ph.D. Michigan State University, "A Simulation Analysis of Policies for the Northern Colombia Beef Cattle Industry."

Poroor Radhakrishnan, B.S. University of Canterbury, 1966; M.A. Stanford University, 1969; Ph.D. Stanford University, "The Role of Rubber in the West Malaysian Economy."

Alfredo Roa, B.S. Universidad del Valle, 1963; M.A. University of Florida, 1964; Ph.D. Michigan State University, "Rural-Urban Migration and Its Relation to Unemployment in the Urban Area of Valle del Cauca, Colombia."

John Davison Shillingford, B.S. University of the West Indies, 1966; M.S. Cornell University, 1970; Ph.D. Cornell University, "Financial Potential and Welfare Implications of Sugar Cane Harvest Mechanization on Jamaican Plantations."

Stephen M. Smith, B.A. University of Pennsylvania; M.S. University of Wisconsin; Ph.D. University of Wisconsin, "Changes in Farming Systems, Intensity of Operation, and Factor Use Under an Agrarian Reform Situation: Chile, 1965/66–1970/71."

Pham Duc Tu, B.S.A. College of Agriculture, Saigon, 1965; M.S. University of Hawaii, 1969; Ph.D. University of Hawaii, "A Simulated Study of Growth and Employment in Hawaii."

Peter George Warr, B.S. University of Sydney, 1968; M.A. Stanford University, 1970; Ph.D. Stanford University, "The Theory of Shadow Pricing."

Ronald Doyle Weddel, B.A. University of Texas, 1966; M.A. University of Texas, 1968; Ph.D. University of Tennessee, "Residential Location Model to Minimize Service Delivery Costs on the Rural-Urban Fringe."

7. Environmental Economics

Muhammad Ashraf, B.S. West Pakistan Agricultural University, 1962; M.S. West Pakistan Agricultural University, 1964; Ph.D. University of Massachusetts, "Optimum Dairy Farm Organization in Relation to Water Quality in Massachusetts."

Richard W. Carkner, B.S. Washington State University, 1965; M.S. Oregon State University, 1968; Ph.D. Michigan State University, "A Case Study

of the Economic Impacts of Farm Soil Loss Controls."

Donald Vetsel DeBord, B.S. Ohio State University, 1966; M.S. North Carolina State University, 1970; Ph.D. North Carolina State University, "Demand for and Cost of Salt Marsh Mosquito Abatement."

David L. Forrester, B.S. Purdue University, 1968; M.S. Purdue University, 1972; Ph.D. Michigan State University, "The Effects of Selected Water Pollution Control Rules on the Simulated Behavior of Beef Feedlots, 1974–85."

Richard A. Greenhalgh, B.S. University of Nebraska, 1962; M.S. University of Nebraska, 1964; Ph.D. University of Missouri, "Identification of the Missouri Public's Perception of Natural Resource Problems."

Lawrence Eugene Johnson, B.S. Louisiana State University, 1966; Ph.D. Mississippi State University, "An Economic Model for Estimating the Cost of Detoxifying Pesticide Containers."

Keith R. Leitner, B.S. Southern Illinois University, 1967; M.S. Southern Illinois University, 1969; Ph.D. Kansas State University, "An Analysis of State Programs for Pollution Control as a Factor Influencing Industrial Location."

Mishnuprasad Ssv. Nagadevara, B.S. A.P. Agricultural University, 1968; M.S. U.P. Agricultural University, 1970; Ph.D. Iowa State University, "A Modeling Approach to the Economic Impacts of Local Environmental Controls in Iowa and the Rest of the Country."

Kenneth J. Nicol, B.S. University of Alberta, 1966; M.S. University of Alberta, 1969; Ph.D. Iowa State University, "A Modeling Approach to the Economic and Regional Impacts of Sediment Loss Control."

William Harry Schaffer, B.S. Pennsylvania State University, 1950; M.S. Cornell University, 1960; Ph.D. Cornell University, "An Economic Analysis of Nitrogen, Phosphorus, and Soil Loss from Agricultural Production Affecting Water Quality in a Small New York Watershed."

George F. Smith, B.S. University of Connecticut, 1963; M.S. Montana State University, 1967; Ph.D. University of Tennessee, "An Evaluation of Environmental Quality: Opportunity Costs of Channelization and Land Use Change in the Floodplain of the Obion-Forked Deer River Basin in Tennessee."

Melvin Earl Walker, Jr., B.S. Alcorn A&M University, 1969; M.S. University of Illinois, 1971; Ph.D. University of Illinois, "An Economic Evaluation of the Impact of the Commercial Nitrogen Control at the Farm Level."

8. Food and Consumer Economics

David G. Barton, B.S. Utah State University, 1967; M.S. Purdue University, 1970; Ph.D. Purdue University, "Physical Distribution System Design: An Application of Mixed Integer Programming to Meat Distributions."

Truong Quang Canh, B.S. University of the Philippines, 1958; M.S. University of North Carolina, 1962; Ph.D. Ohio State University, "Income Instability and Consumption Behavior: A Study of Taiwanese Farm Households 1964–1970."

Loren Victor Geistfeld, B.A. Macalaster College, 1967; Ph.D. University of Minnesota, "A Technical Efficiency Approach to Consumer Decision Making."

Tilmon Kreiling, Jr., B.A. Yale University, 1967; Ph.D. Stanford University, "Empirical Estimation of U.S. Demand for Meat Products."

Benjamin Harrison Sexauer, Jr., B.A. University of California, Santa Barbara, 1968; M.A. Stanford University, 1972; Ph.D. Stanford University, "The Role of Habit Formation and Inventory Adjustment in a Dynamic Demand Model."

Larry Ray Shonkwiler, B.S. University of Illinois, 1968; M.S. University of Illinois, 1969; Ph.D. Ohio State University, "Consumer Attitudes Toward Food Store Selection and Perception of Store Conduct: Implications for Market Performance."

Paulo Silva, B.S. Federal University of Ceara, 1964; M.S. Federal University of Vicosa, 1967; Ph.D. Michigan State University, "Estimating Least Cost Human Diets in the Northeast of Brazil with Stochastic Programming-Theoretical Issues and Policy Implications."

9. Human Resource Development

Robert O'Neal Coppedge, B.B.A. New Mexico State University, 1965; M.S. New Mexico State University, 1967; Ph.D. Oregon State University, "An Economic Analysis of Some Factors Related to Low Income in Rural Oregon with Special Reference to the Role of Education."

Vincent Cusumano, B.S. Bradley University, 1966; M.A. University of Kentucky, 1970; Ph.D. University of Kentucky, "An Economic Interpretation of Local School District Behavior: The Effects of Intergovernmental Grants on the Provision of Educational Services in Kentucky."

James Edward Easley, Jr., B.A. North Carolina State University, 1967; M.A. North Carolina State University, 1968; Ph.D. North Carolina State University, "Expenditures per Child in an Economic Model of Fertility."

David Eugene Ervin, B.S. Ohio State University, 1967; M.S. Ohio State University, 1969; Ph.D. Oregon State University, "Income Determination for Production Workers in Oregon's Wood Products Industry: A Human Capital Approach."

Michael Joseph Hay, B.A. University of Minnesota, 1967; Ph.D. University of Minnesota, "An Economic Analysis of Rural-Urban Migration in Tunisia."

Peter Norman Hopcraft, B.S. Cornell University,

1965; A.M. Stanford University, 1967; A.M. Stanford University, 1968; Ph.D. Stanford University, "Human Resources and Technical Skills in Agricultural Development: an Economic Evaluation of Educative Investments in Kenya's Small Farm Sector."

George Morse, B.S. University of Maine; M.S. Purdue University; Ph.D. University of Wisconsin, "The Neighborhood Benefit Investment Hypothesis for Public Education: An Econometric Study of Wisconsin School Districts."

10. Institutions

James Ronald Baarda, B.S. Iowa State University, 1963; J. D. University of Denver College of Law, 1969; Ph.D. University of Florida, "An Economic Analysis of Alternative Revenue Generating Policies For State Financing."

11. Land Tenure

Muhammad Arshad Chawdhry, B.S. West Pakistan Agricultural University, 1967; M.S. West Pakistan Agricultural University, 1969; M.S. University of Illinois, 1972; Ph.D. University of Illinois, "Effect of Land Tenure on Resource Use and Productivity in Agriculture: A Case Study of Punjab, Pakistan."

12. Marketing and Location

Nasser A. Aulaqi, B.S. New Mexico State University, 1969; M.S. New Mexico State University, 1971; Ph.D. University of Nebraska, "A Projective Programming Information Model for the U.S. Beef and Pork Sectors."

Renny J. Avey, B.S. California State Polytechnic College, 1969; M.S. Oregon State University, 1972; Ph.D. University of Hawaii, "An Econometric Analysis of Beef, Pork, and Chicken Consumption in Hawaii—A Synthesis of Three Approaches."

James E. Berry, B.S. Murray State University, 1962; M.S. University of Kentucky, 1964; Ph.D. University of Kentucky, "An Economic Analysis of Retail Fertilizer in Northeast Thailand."

Donald Hubert Graves, B.S. Purdue University, 1959; M.S.F. University of Florida, 1960; Ph.D. University of Kentucky, "Alternative Marketing Strategies: A Linear Programming Application to Kentucky Sawmills."

Dennis Ray Lifferth, B.S. Brigham Young University, 1968; M.S. Iowa State University, 1970; Ph.D. Iowa State University, "An Economic Analysis of Alternative Rail-Based Grain Distribution Systems."

Marvin Bruce Martin, B.S. Iowa State University, 1968; Ph.D. Iowa State University, "An Economic Analysis of Quality and Grading in Corn Marketing."

Kenneth Milton Menz, B.S. University of Sydney, 1967; M.S. University of Minnesota, 1969; Ph.D. University of Minnesota, "The Impact of Mobile Processing Plants on the Production and Distribution of Frozen Peas."

Carl William O'Connor, B.S. California State Polytechnic College, 1968; M.S. University of Massachusetts, 1972; Ph.D. Oregon State University, "Measurement of the Economic Efficiency of Selected Vertically Coordinated Meat Handling Systems."

Thomas Rollins Pierson, B.S. Cornell University, 1966; M.S. Purdue University, 1968; Ph.D. Cornell University, "Economics of Size in Grocery Distribution Centers."

Peter Karl Pollak, Doctor's Degree, Vienna University of Economics, 1966; Ph.D. University of Minnesota, "Economic Analysis of Oilseed Markets in Thailand."

Saiyed Mehdi Haider Rizvi, B.Sc. University of Peshawar, 1955; M.Sc. University of Punjab, 1958; M.Sc. Colorado State University, 1961; M.Ed. Colorado State University, 1961; Ph.D. University of Alberta, "Marketing Boards in Canada—An Evaluation of Their Quota Policies with Special Reference to the Chicken Broiler Industry."

Larry S. Salathe, B.S. University of Wisconsin; M.S. University of Wisconsin; Ph.D. University of Wisconsin, "An Econometric Simulation Model of Wisconsin's Dairy Industry."

Bai Yung Sung, B.S. Seoul National University, 1966; M.S. Seoul National University, 1970; Ph.D. University of Minnesota, "The Demand for Fertilizer in Korea."

Peter Eliezer Temu, B.S. Makerere University, 1962; Ph.D. Stanford University, "Marketing Board Pricing and Storage Policy with Particular Reference to Maize in Tanzania."

Daniel Stephen Tilley, B.S. Iowa State University, 1970; M.S. Iowa State University, 1973; Ph.D. Iowa State University, "Hog Producers' Marketing Decisions."

13. Natural Resource Economics

Jean F. Abgrall, license Faculte De Droit Rennes, France, 1968; Ph.D. University of Rhode Island, "A Cost-Production Analysis of Trap and Hand Line Fishing in Puerto Rico."

Stephen Oliver Andersen, B.S. University of California, 1970; Ph.D. University of California, Berkeley, "Economics of Nuclear Power Plant Location with Emphasis on the Coastal Zone."

Affendi Anwar, Ph.D. Montana State University, "Optimal Economic Control Strategies in Forest Resource Management."

Henry Beale, B.A. Oberlin College, 1965; M.A. University of Chicago, 1970; Ph.D. University of Chicago, "The Use of Capitalized Values of Land and Water Rights in Evaluating Irrigation Projects."

Metin Caglar, B.S. Istanbul University, 1963; M.S. Nebraska University, 1969; Ph.D. Iowa State University, "Optimization of Intraseasonal Water Allocation."

James William Currie, B.S. University of Maine, 1964; M.S. Oregon State University, 1970; Ph.D. Oregon State University, "A Model for Simulating River and Reservoir Temperatures with Applications for Anadromous Fish Management."

Warren W. Gerber, B.S. University of Minnesota, 1964; M.S. University of Nebraska, 1972; Ph.D. University of Nebraska, "Management Strategies for Groundwater."

Mark Rand Gustafson, B.S. University of Nebraska, 1967; M.S. University of Nebraska, 1968; Ph.D. University of California, Berkeley, "An Analysis of Selected Economic Effects of Rural Subdivision Development Activity upon the Public and Private Sectors of Tuolumne County, California, 1970."

Uri Horowitz, B.S. Hebrew University of Jerusalem, 1967; M.S. Hebrew University of Jerusalem, 1970; Ph.D. Iowa State University, "A Dynamic Model Integrating Demand and Supply Relationships for Agricultural Water, Applied to Determining optimal Intertemporal Allocation of Water in a Regional Water Project."

Alan Scott Krug, B.S. Pennsylvania State University, 1955; M.S. Virginia Polytechnic Institute and State University, 1960; Ph.D. Pennsylvania State University, "A Model for Evaluation of Affiliates of the National Wildlife Federation."

Gary Dean Lynne, B.S. North Dakota State University, 1966; M.S. North Dakota State University, 1969; Ph.D. Oregon State University, "Multiple Objective Planning Procedures in Water Resource Development: The Trade-Off Ratio."

Paul William Merkens, B.S. Antioch College, 1963; M.S. University of California, Berkeley, 1965; Ph.D. Cornell University, "Risk Acceptance in Public Water Supply: A New York City Case Study."

Neil Meyer, B.S. University of Minnesota; M.S. University of Wisconsin; Ph.D. University of Wisconsin, "Interregional Impacts of Alternative Water Policies for Irrigation in the Western United States: A Quantitative Assessment."

David Omodiaogbe Oboh, B.S. University of Ibadan, 1968; M.S. University of Ibadan, 1971; Ph.D. Oklahoma State University, "Economies of Size and Socio-Economic Impacts of Rural Water Districts in Oklahoma."

Giles Thomas Rafsnider, B.S. Utah State University, 1965; M.S. University of Nevada, 1967; Ph.D. University of Massachusetts, "Economic Analysis of Timber Harvest Level Changes Using a 1967 Input-Output Model of the Idaho Economy."

C. B. A. Ross, B.Sc. University of West Indies, 1964; M.Sc. University of Alberta, 1968; Ph.D. University of Manitoba, "The Estimation of Demand for and Benefits Derived from Outdoor Recreation at Proposed Sites in the Souris River Basin, Manitoba."

Ivar E. Strand, B.A. University of Rochester, 1967; M.A. University of Rhode Island, 1972; Ph.D. University of Rhode Island, "Density Dependent Recruitment and Stochastic Considerations in the Management of a Multi-Species Fishery."

Charles Heckman Strauss, B.S. Pennsylvania State University, 1958; M.A. Pennsylvania State University, 1968; Ph.D. Pennsylvania State University, "An Economic Analysis of a Public Outdoor Recreation Supply System."

14. Production Economics and Management

Edgar J. Ariza-Nino, B.S. University of Arizona; M.S. University of Arizona; Ph.D. University of Wisconsin, "Beef Cattle Production: A Microeconomic Growth Curve Model with Special Reference to Sire Evaluation Under Tropical Conditions."

Christopher David Sloan Bartlett, B.Sc. London University, 1961; M.S. University of Toronto, 1963; A.M. Stanford University, 1964; Ph.D. Stanford University, "Factors Affecting the Spread of Rain-Grown Cotton in Tropical Africa."

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Articles

Notes

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American Journal of Agricultural Economics

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August 1975

AMERICAN AGRICULTURAL ECONOMICS ASSOCIATION

American Journal of Agricultural Economics

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Articles

Notes

Publications

Books Reviewed

News

Articles

The Farm-Retail Price Spread in a Competitive Food Industry

Bruce L. Gardner

Consistency with market equilibrium places constraints on the pricing policies of food marketing firms in a competitive industry. This paper examines the implications of simultaneous equilibrium in three related markets: retail food, farm output, and marketing services. From equations representing the demand and supply sides of each market, elasticities are generated which show how the farm-retail price spread changes when retail food demand, farm product supply, or the supply function of marketing services shifts. Implications for the viability of simple markup pricing rules and the determinants of the farmer's share of the food dollar are discussed.

Key words: farm-retail price spread, marketing margin, market equilibrium, competition.

This study examines the consequences of competitive equilibrium in product and factor markets for the relationship between farm and retail food prices. The investigation is based on a one-product, two-input model developed by Allen and Hicks and since applied to many issues at the industry level. Notable agricultural examples are the papers of Brandow and Floyd. The model is used in this paper to generate quantifiable predictions about how various shifts in the demand for and supply of food will affect the retail-farm price ratio and the farmer's share of retail food expenditures. The results have implications for the viability of simple rules of markup pricing by marketing firms. In general, the markup must change whenever demand or supply shifts in order to be compatible with market equilibrium. Moreover, the markup will be forced to change in different ways depending on whether price movements originate from the retail demand or farm supply side. Related implications concern the consequences of retail price ceilings and farm price floors, the elasticity of price transmission, and the determinants of changes in the farmer's share of the food dollar.

Bruce L. Gardner is an associate professor of economics at North Carolina State University.

The author acknowledges help and criticism from Ronald A. Schrimper, J. B. Bullock, Gerald A. Carlson, John Ikerd, Paul R. Johnson, E. C. Pasour, and the *Journal* reviewers.

The Model

Consider a competitive food marketing industry using two factors of production, purchased agricultural commodities (a) and other marketing inputs (b), to produce food sold at retail (x). The marketing industry's production function is

$$x = f(a, b). \tag{1}$$

It is assumed to yield constant returns to scale. The retail food demand function is

$$x = D(P_x, N), \tag{2}$$

where P_x is the retail price of food and N is an arbitrary exogenous demand shifter which for purposes of specificity will be called population.

The model is completed by equations representing the markets for b and a. On the demand side, firms are assumed to want to buy the profit-maximizing quantities of b and a, which implies that value of marginal product equals price for both

$$P_b = P_x \cdot f_b \tag{3}$$

and

$$P_a = P_x \cdot f_a, \tag{4}$$

where f_b and f_a are the partial derivatives of x with respect to b and a.

The input supply equations are

$$(5) \qquad P_b = g(b,T),$$

the supply function of b to the food marketing industry, and

$$(6) \qquad P_a = h(a,W),$$

the supply function of agricultural output. The exogenous shifters of marketing input and farm product supply are represented by T and W. For purposes of specificity, W may be thought of as a weather variable for which higher values increase P_a (e.g., an index of drought), and T as a specific tax on marketing inputs which makes them all more expensive.

This system contains six equations in six endogenous variables (x,b,a,P_x,P_b,P_a). Under normal conditions (where the demand function has negative and the supply functions have nonnegative slopes), there will be a unique equilibrium for given values of the exogenous variables. At this equilibrium, the values of the six endogenous variables, and hence the farm-retail spread, are determined. This price spread may be measured by the difference between the retail and farm price, $P_x - P_a$, by the ratio of the prices, P_x/P_a, by the farmer's share of the food dollar, aP_a/xP_x, or by the percentage marketing margin, $(P_x - P_a)/P_a$. This paper focuses on the retail-farm price ratio, the closely related percentage margin, $P_x/P_a - 1$, and the farmer's share of retail food expenditures.

Effect of a Food Demand Shift on the Retail-Farm Price Ratio

The effects of a shift in retail demand on market equilibrium are analyzed by differentiating equations (1) to (6) with respect to N, while W and T are held constant. The six equations can be immediately reduced to three (one equation for the final product market and one for each input) by equating (1) and (2) to eliminate x, (3) and (5) to eliminate P_b, and (4) and (6) to eliminate P_a.

Beginning with the market for a, equations (4) and (6), the new equation is

$$(7) \qquad h_a \frac{da}{dN} = P_x \frac{df_a}{dN} + f_a \frac{dP_x}{dN}.$$

The df_a term of equation (7) must be expanded further. It is not simply the second partial derivative of x with respect to a (which will be written f_{aa}). It also brings in the amount of b that a has to work with as

$$(8) \qquad \frac{df_a}{dN} = f_{aa} \frac{da}{dN} + f_{ab} \frac{db}{dN}.$$

Substituting equation (8) into (7) yields

$$(9) \quad h_a \frac{da}{dN} = P_x f_{aa} \frac{da}{dN} + P_x f_{ab} \frac{db}{dN} + f_a \frac{dP_x}{dN}.$$

Next, analyze the b market by combining equations (3) and (5) and differentiating:

$$(10) \quad g_b \frac{db}{dN} = P_x f_{bb} \frac{db}{dN} + P_x f_{ba} \frac{da}{dN} + f_b \frac{dP_x}{dN}.$$

Equation (10) holds the b market in equilibrium while the relationship between dP_x and dP_a is examined. Similarly, the third equation specifies equilibrium in the x market by differentiating equations (1) and (2) combined:

$$(11)\ f_a \frac{da}{dN} + f_b \frac{db}{dN} = D_{P_x} \frac{dP_x}{dN} + D_N.$$

Equations (9)-(11) can be solved for da/dN, db/dN, and dP_x/dN. The solution is made more intelligible by converting all derivatives to elasticities. Details of the necessary manipulations are presented in an appendix. The result is the three equation system:

$$(12) \quad 0 = -\left(\frac{S_b}{\sigma} + \frac{1}{e_a}\right) E_{aN} + \frac{S_b}{\sigma} E_{bN} + E_{P_xN},$$

$$(13) \quad 0 = \frac{S_a}{\sigma} E_{aN} - \left(\frac{S_a}{\sigma} + \frac{1}{e_b}\right) E_{bN} + E_{P_xN},$$

and

$$(14) \quad \eta_N = S_a E_{aN} + S_b E_{bN} - \eta E_{P_xN}.$$

Equation (12) pertains to the market for a, (13) to b, and (14) to x; S_a and S_b are the relative shares of a and b, e.g., $S_a = aP_a/xP_x$; σ is the elasticity of substitution between a and b; η is the price elasticity of demand for x; e_a and e_b are the own price elasticities of supply of a and b; η_N is the elasticity of demand for x with respect to N; and E_{aN}, E_{bN}, and E_{P_xN} are total elasticities which tell how the first subscripted variable responds to a change in the second.[1]

[1] The capital E's are elasticities which take into account equilibrating adjustments in all three markets simultaneously; e_a, e_b, and η are partial elasticities which refer to movements along the input supply and product demand functions. All the elasticities

The question to be investigated is how P_x/P_a changes when the demand for food shifts. The answer can be expressed as the elasticity of P_x/P_a with respect to N. This elasticity is equal to the difference between E_{P_xN} and E_{P_aN}, both of which can be obtained from the system of equations (12) to (14). The result (derived in the appendix) is

$$(15) \qquad E_{P_x/P_aN} = \frac{\eta_N S_b(e_a - e_b)}{D},$$

where D is a function of σ, η, e_a, e_b, and S_a.[2] The denominator has no intuitively clear meaning but is positive in all normal cases ($\eta < 0$ and e_a and $e_b \geqslant 0$). Therefore, the numerator normally determines the sign of equation (15).

Because of the way the original model was constructed, equation (15) will be more readily applicable to some situations than others. In reality, of course, there are many marketing activities and many marketing inputs. The present model assumes that these can all be lumped together into a single production function with a single marketing input, b. Following the usual requirements for aggregation, this assumption should cause no analytical difficulties so long as the relative prices of the components of b are constant. Thus, equation (15) will be helpful in understanding how shifts in food demand affect agricultural product prices relative to all marketing inputs as a group, but will not be helpful in situations where substantial relative price changes within the set of marketing inputs are induced.

There may also be an aggregation problem with the quantity of retail food, x, depending on the context in which the model is applied. If x is taken to be an aggregate of all food, it must be assumed that the relative prices of the various food products are held constant. Thus, the exogenous shift in demand should be thought of as one applying to all forms of food.

On the other hand, if the context in which the model is applied is a relatively narrowly defined product, say, wheat, the aggregation problems for both x and b may be less serious.[3] For a case like wheat as the farm product and bread as the retail product, what is the probable sign of equation (15)? Since wheat is a specific factor to the x industry, while the components of b (labor, transportation, packaging, etc.) generally are not, and since a is land intensive, it seems likely that $e_a < e_b$. In this case, when the demand for food shifts to the right, P_x/P_a falls. Therefore, the retail-farm price ratio is expected to decline when population (or any other exogenous food demand shifter) increases.

An interesting special case arises when $e_a = e_b$. In this case P_x/P_a is unchanged when the demand for food shifts. Thus, a fixed percentage markup rule used by marketing firms is viable in the sense that competitive forces will not require the markup to change when retail food demand shifts. In general, however, $e_a \neq e_b$ and a fixed percentage markup will not be viable in this sense.

Equation (15) also helps in understanding the role of σ, the elasticity of substitution between a and b in the marketing industry. Suppose N increases, and $e_a < e_b$. Then the price of raw farm product relative to marketing inputs increases, creating an incentive to substitute the latter for the former. In the wheat example, additional labor may be used to reduce grain wastage in processing operations, and the use of pest and spoilage control may increase.[4] However, in many marketing contexts the opportunities for substitution appear limited. This would be reflected in equation (15) by a small value of σ. Since σ appears only in the denominator and with a positive sign, the smaller σ is the more volatile the retail-farm price ratio.

The economic reason for this result can be illustrated with reference to an increase in retail demand for food. The demand shift increases the derived demand for both farm products and the nonagricultural inputs used in the food marketing industry. But so long as the two elasticities of supply are different ($e_a \neq e_b$), their relative prices must change. How much P_a/P_b will change depends on the degree to which a and b can be substituted in the

are partial in the sense that the exogenous variables T and W are held constant.

[2] $D = -\eta(S_b e_a + S_a e_b + \sigma) + e_a e_b + \sigma(S_a e_a + S_b e_b)$.

[3] The model applied separately to each of a set of narrowly defined retail products would still have implications for the average or aggregate farm-retail price spread. For example, a shift in demand towards relatively b-intensive products (such as TV dinners) would reduce the aggregate farmer's share even if the share for any particular product remained unchanged.

[4] Analytically troublesome issues are raised by the possibility of changing the nature of the product when P_a/P_b rises, for instance, economizing on wheat use by milling poorer quality wheat or even introducing a bit of sawdust into the cracked wheat bread. One may question in such a case whether our observations are of movements along a well-defined demand curve and production function. This is not, of course, a difficulty peculiar to the present model. It pertains to almost any situation in which substitution in production is possible. Moreover, if we were purist enough to say that the nature of a food product changed whenever its farm level price changed, it could also put a quick end to empirical studies of retail food demand.

marketing process. The greater σ is, the less P_a/P_b will change when P_x is changing. In the extreme case when $\sigma \to \infty$, equation (15) approaches zero and P_x/P_a is constant.

In the more realistic limiting case in which $\sigma \to 0$, the Marshallian derived demand model applies (Friedman, chap. 7). In this case the propositions concerning e_a, e_b, and η in this and the following sections can be derived graphically using the methods of Tomek and Robinson (chap. 6).

Effect of a Farm Product Supply Shift on the Retail-Farm Price Ratio

A shift in equation (6) is analyzed by taking derivatives with respect to W, while dN and dT are held equal to zero. When the results are converted to elasticities, a system of three equations identical to equations (12) to (14) results, except that all E's have W as their second subscript; η_N becomes zero in equation (14), and e_W (the elasticity of P_a with respect to W) replaces zero in equation (12).

Solving this new system for the elasticity of P_x/P_a with respect to a change in W yields[5]

$$(16) \qquad E_{P_x/P_a, W} = \frac{e_W S_b e_a(\eta - e_b)}{D}.$$

Equation (16) differs from equation (15) in that for all normal cases, $E_{P_x/P_a, W}$ is negative. Thus, the percentage difference between P_x and P_a will fall when P_a rises as a result of a leftward shift in the supply function of agricultural output. Conversely, an exogenous event that reduces P_a by increasing a, such as a technical improvement in crop production, will widen the percentage difference between P_x and P_a. The economic reason for this result can be explained as follows. When farm product supply shifts to the right, both P_x and P_a will tend to fall. But the increase in x will require additional marketing inputs. So long as $0 \leq e_b < \infty$, P_b must therefore rise, increasing the cost of marketing relative to farm inputs and hence the ratio P_x/P_a.

As was the case in equation (15), σ plays a moderating role in that the larger σ is, the less a given shift in W will change P_x/P_a.

The responsiveness of P_x/P_a to W varies substantially with the context being considered. For example, in a very short-run context for a narrowly defined product, capacity constraints in marketing activities may make e_b quite small, so that P_x/P_a is especially volatile. Another extreme case would be (external) economies of scale in marketing activities, which would make $e_b < 0$ and could even reverse the sign of equation (16). In this case, an increase in farm product supply could conceivably reduce P_x/P_a by reducing the price of marketing services as output increases. A final interesting special case is that in which marketing inputs are perfectly elastic in supply (a long-run, nonspecific factor case). In this case, P_b remains constant, but an increase in farm supply will still increase P_x/P_a. This occurs because even though P_b is absolutely unchanged, it is increased relative to P_a. Hence the relative contribution to retail food costs accounted for by marketing inputs will increase.

Effect of a Marketing Input Supply Shift on the Retail-Farm Price Ratio

A shift in equation (5) is analyzed by taking derivatives with respect to T, while dN and dW are equal to zero. In this case, the system of equations corresponding to equations (12) to (14) is changed as follows: η_N becomes zero in equation (14), e_T (the elasticity of P_b with respect to T) replaces zero in equation (13), and all E's have T as their second subscript. Solving this system for the elasticity of P_x/P_a with respect to T yields

$$(17) \qquad E_{P_x/P_a, T} = \frac{e_T S_b e_b(e_a - \eta)}{D}.$$

Equation (17) has the same form as equation (16) except that e_a and e_b are interchanged in the numerator and the sign is reversed. Equation (17) will be positive in all normal cases, so that the percentage margin between P_x and P_a will increase when P_b rises as a result of a specific tax on marketing inputs. Thus, while an exogenous change that decreases agricultural supply will decrease the retail-farm price ratio, the same kind of change in the supply of marketing inputs will increase the ratio.

Equation (17) seems more limited in its applicability than equations (16) or (15) due to the aggregation problem. It is difficult to think of exogenous shifters of marketing input supply that will affect all the components of b proportionally. Technical progress, for example, will typically be associated with a particular marketing input or activity. This will

[5] Derivation outlined in appendix.

Table 1. Elasticities of P_x/P_a with Respect to Shifts in Retail Food Demand, Farm Product Supply, and Marketing Input Supply

Parameter Values					$E_{P_x/P_a,N}$	$E_{P_x/P_a,W}$	$E_{P_x/P_a,T}$
σ	e_a	e_b	η	S_b	eq. (15)[a]	eq. (16)[a]	eq. (17)[a]
0.5	1.0	2.0	−0.5	0.5	−0.13	−0.33	0.40
0	1.0	2.0	−0.5	0.5	−0.18	−0.46	0.54
0	1.5	2.0	−0.5	0.5	−0.06	−0.48	0.52
0	2.0	2.0	−0.5	0.5	0	−0.50	0.50
0	2.0	1.0	−0.5	0.5	0.18	−0.54	0.46
0	1.0	2.0	−1.0	0.5	−0.14	−0.43	0.57

[a] The values of η_N in eq. (15), e_W in eq. (16), and e_T in eq. (17) are set equal to 1. Thus, the elasticity of P_x/P_a with respect to N measures the percentage response in P_x/P_a to a change in N sufficient to shift the demand for x by 1% at given prices.

change the relative prices of the components of b, hence violating a necessary condition for aggregation.

To examine further the anatomy of equations (15), (16), and (17), they can be evaluated at hypothetical parameter values. Let $S_a = 0.5, \eta = -0.5, e_a = 1.0, \sigma = 0.5$, and $e_b = 2.0$. The resulting values of P_x/P_a from equations (15) to (17) are shown in the first line of table 1. The −0.13 elasticity means that a change in population sufficient to generate a 10% rightward shift in retail demand reduces P_x/P_a by approximately 1.3%.[6] Thus, the price ratio (and percentage marketing margin) fall, though quantitatively the response is small.[7]

Keeping the other parameter values the same, let σ be zero. In this case the change in the marketing margin is larger (line 2 of table 1). The economic reason for this result was discussed above with reference to a shift in retail demand.

A crop like sweet potatoes, which uses a relatively small fraction of the land suitable for it, may have e_a larger than 1.0, especially in a long-run context. Lines 3 and 4 of table 1 examine what happens when e_a increases, holding the other parameters constant. From line 5, when $e_a > e_b$, the percentage margin increases when P_a and P_x rise. In this case, when retail demand increases, it is the nonagricultural inputs in marketing that become relatively scarce. However, when the increase in P_a and P_x is induced from a shift in the agricultural supply function, equation (16), P_x/P_a falls when prices increase no matter what e_a is. In this case there is given a change in P_a, say, induced by drought. Of course, e_a enters indirectly in that the larger e_a is, the worse the drought will have to be to obtain a given increase in P_a. (For example, the effect on the price of chickens when several million contaminated birds were killed in Mississippi depended on the degree to which other chicken producers could increase supply in response.) Line 6 shows the consequences of a more elastic demand curve at the retail level, the other parameters remaining the same as in line 2.

Price Supports and Price Ceilings

Price Control on x

If a price ceiling lower than the market-clearing price is imposed on a food product at the retail level, but not at the farm level, what effect will this have on the retail-farm price ratio? This question can be answered by introducing P_x as an exogenous variable in place of the demand equation (2). The resulting system can be solved to obtain

$$(18) \qquad E_{P_a\bar{P}_x} = \frac{\sigma + e_b}{\sigma + S_a e_b + S_b e_a},$$

where $\bar{P}_x$ equals the legal maximum price.[8] If $e_a = e_b$, then $E_{P_a\bar{P}_x} = 1$, and a legislated reduction in P_x will reduce P_a by the same

[6] An approximation because equations (15), (16), and (17) pertain to small changes. The approximation for large changes would be better the closer equations (2), (5), and (6) are to constant own-price elasticity, i.e., log-linear form, and the closer equation (1) is to a CES form.

[7] If the marketing margin is expressed as a percentage markup over the farm level price, then P_x/P_a and the margin are directly related as P_x/P_a = 1 + marketing margin.

[8] No derivation of equation (18) is given because this same result is presented in Floyd (p. 151) to show the effect of a farm level price support on the price of land and labor in agriculture. Even though Floyd considers a minimum price and equation (18) a legal maximum price, the results are the same because in both cases the restriction moves us along the product supply curve. Floyd accomplishes this for the minimum price by having the government buy all that is offered at the support price. In the maximum price case, excess demand will exist at $\bar{P}_x$, requiring nonprice rationing.

percentage. In this case, the percentage marketing margin is unchanged. It seems likely, however, that $e_a < e_b$, which implies that $E_{P_a\bar{P}_x} > 1$. In this case, P_a falls by a greater percentage than P_x so that the percentage margin widens when price controls are imposed.

The sign of equation (18) is positive, implying that an effective price ceiling on retail food will always reduce farm level prices. The only exception would be if $e_a \rightarrow \infty$. In this case, a price ceiling on P_x would leave P_a unchanged. The reason for this result is that the price ceiling on x always reduces the derived demand for a, even though consumers want to buy more x at the lower P_x. Derived demand is reduced because competitive marketing firms cannot afford to pay as much for a with the price ceiling as they could without one. The exception when $e_a \rightarrow \infty$ arises because when a is perfectly elastic in supply, its price is unaffected by a shift in the derived demand for a.

Price Control on a

If the price of a is kept at a legislated level by means of production controls, what effect will this have on the retail-farm price ratio? This question can be answered by leaving out the supply equation (6) and introducing a as an exogenous variable. The resulting system can be solved to obtain

$$(19) \qquad E_{P_x\bar{P}_a} = \frac{S_a(\sigma + e_b)}{e_b + S_a\sigma - S_b\eta},$$

where $\bar{P}_a$ is the legislated price support level. In order for a percentage marketing margin to remain unchanged, $E_{P_x\bar{P}_a}$ must equal 1. As long as $e_b > \eta$, that is, in all normal cases, equation (19) will be less than 1.[9] Therefore, a production control program that raises P_a will raise P_x by a smaller percentage, and the percentage margin will narrow.

The Elasticity of Price Transmission and the Elasticity of Derived Demand

The percentage change in P_x associated with a change in P_a is equal to the reciprocal of equation (18) when the change originates in the x market and to equation (19) when the change originates in the a market (see equations [A.10–11]). Since equations (18) and (19) are different, the value of the elasticity of price transmission is obviously not independent of whether the exogenous changes that generate our observations come from the demand for x or the supply of a. If the supply of a is the source of observed price changes, then equation (19) applies, and $E_{P_xP_a}$ is less than one. But if shifts in food demand are responsible for observed price changes, equation (18) applies and $E_{P_xP_a}$ will be closer to unity, and will exceed it if $e_a > e_b$, i.e., if marketing inputs are more nearly fixed in supply than are farm products.

A function such as George and King's (p. 57),

$$P_a = \alpha + \beta P_x,$$

even if it fits perfectly conditions generated by farm supply shifts, would not yield estimates of α and β applicable to conditions generated by retail demand shifts. Estimation when both farm supply and retail demand are shifting would yield an elasticity of price transmission that is a hybrid of equations (18) and (19).[10]

George and King use the elasticity of price transmission to derive farm-level elasticities from retail price elasticities of demand. In the terminology of this paper, their result (p. 61) is

$$(20) \qquad E_{aP_a} = (\eta)(E_{P_xP_a}).$$

This equation can be misleading. The problem is that George and King, following Hildreth and Jarrett (p. 108), do not distinguish between quantities of product at the farm and retail level. They assume that $x \equiv a$. This assumption is of no great analytical significance in the case of fixed proportions, since a can be transformed into x by means of a constant production coefficient. Although fixed proportions may not be an unreasonable assumption in many marketing contexts, there are several commodities examined by George

[9] The condition for equation (19) being less than 1 is

$$s_a\sigma + S_a e_b < e_b + S_a\sigma - S_b\eta.$$

Subtracting $S_a\sigma + e_b$ from both sides and dividing by $-S_b$ yields $e_b > \eta$.

[10] There is one other $E_{P_xP_a}$ relationship that arises indirectly when the exogenous event that changes both P_x and P_a is a shift in marketing input supply, T in equation (5). This elasticity is

$$E_{P_xP_a} = \frac{\sigma + e_a}{\sigma + \eta} \ (N,\ W \text{ constant}).$$

This case is especially interesting in that it is the only one that can account, within the confines of this model of this paper, for a simultaneous fall in P_a and a rise in P_x. While equations (18) and (19) are positive for all normal parameter values, this elasticity is not. It will be negative whenever $\sigma < |\eta|$.

and King for which the ratio of a to x may vary.

A more general statement of the relationship between the retail elasticity of demand for food, η, and the farm level elasticity of demand, E_{aP_a}, is readily obtainable from the original system of equations (1)–(6). As Floyd (p. 153) shows, the elasticity of demand for a, which is identical to the elasticity of factor demand found by Hicks (p. 244), is

$$(21) \qquad E_{aP_a} = \frac{\eta\sigma + e_b(S_a\eta - S_b\sigma)}{e_b + S_a\sigma - S_b\eta}.$$

Whether E_{aP_a} is greater than or less than η depends on the relative size of σ and (the absolute value of) η. The derived demand function for a will be less elastic than the retail demand function if and only if $\sigma < |\eta|$. If $\sigma = |\eta|$, then equation (21) yields $E_{aPa} = \eta$. The retail and farm level elasticities are equal. If $\sigma > |\eta|$, then the derived demand function is more elastic than is the demand function for the final product.[11] In the case of fixed proportions, since $\sigma = 0$, σ is always less than $|\eta|$. Therefore, in this case, farm level demand is always less elastic than retail level demand.

To show how this general approach fits in with the elasticity of price transmission as used by George and King, replace the left-hand side of equation (20) by E_{aP_a} from equation (21). Replace the right-hand side of equation (20) by equation (19) times η. These substitutions yield

$$\frac{\eta\sigma + e_b(S_a\eta - S_b\sigma)}{e_b + S_a\sigma - S_b\eta} \neq \frac{\eta S_a(e_b + \sigma)}{e_b + S_a\sigma - S_b\eta}.$$

In general, the two sides are not equal. But if $\sigma \to 0$, then

$$\frac{S_a e_b \eta}{e_b - S_b\eta} = \frac{S_a e_b \eta}{e_b - S_b\eta}$$

and the George and King approach is correct.

[11] For instance, if $\eta = -0.2$, $\sigma = 0.5$, $S_a = 0.5$, and $e_b = 1$, the value of equation (21) is

$$E_{aP_a} = \frac{0.5(-0.2) + 1(0.5(-0.2) - 0.5(0.5))}{1 + 0.5(0.5) - 0.5(-0.2)} = -0.33.$$

The farm level demand elasticity is substantially greater.

To obtain the general condition for $E_{aP_a} > \eta$, note that this occurs iff $E_{aP_a}/\eta > 1$. From equation (21), this occurs when

$$\eta\sigma + e_b(S_a\eta - S_b\sigma) > \eta(e_b + S_a\sigma - S_b\eta).$$

Subtracting $S_a\sigma + S_a e_b$ from both sides, dividing by S_b, and factoring out σ on the left-hand and η on the right-hand side yields $\sigma > -\eta$.

The Farmer's Share of the Food Dollar

The data generated by the U.S. Department of Agriculture on farm-retail price spreads do not distinguish between the price ratio P_a/P_x and relative share aP_a/xP_x (which is S_a in the notation of this paper). The two are the same in the USDA publications because the quantities of farm product are adjusted by means of estimated production coefficients to obtain equivalent units for a and x. Thus, P_a is the value of farm product per unit of x. For example, in the case of pork, the farm price for 1969 is multiplied by 1.97 on the grounds that 1.97 pounds of "live hog equivalent" yields 1 pound of pork sold to consumers (Scott and Badger, p. 115). This substitution of units of x for units of a is strictly correct only in the fixed proportions case.[12] In general, the farmer's share of the food dollar is conceptually quite different from the farm price as a percentage of the retail price of food. This share can be analyzed by the same methods used above to analyze P_x/P_a. It turns out (derivation in appendix) that

$$(22) \qquad E_{S_a N} = \frac{\eta_N S_b(e_a - e_b)(\sigma - 1)}{D},$$

where the parameters and D are as defined in equation (15). Since $D > 0$, the numerator determines the sign of equation (22). There are three interesting cases. (a) If either $e_b = e_a$ or $\sigma = 1$ (the Cobb-Douglas case), then S_a is constant. A shift in demand for food at the retail level will have no effect on the farmer's share. (b) If $e_b > e_a$ and $\sigma < 1$ or if $e_b < e_a$ and $\sigma > 1$, then S_a increases with N. An increase in demand for food will increase the farmer's share. (c) If $e_b > e_a$ and $\sigma > 1$ or if $e_b < e_a$ and $\sigma < 1$, then an increase in the demand for food will decrease the farmer's share.

It seems most likely for any particular food commodity or for an aggregate of such commodities that $e_b > e_a$ (the elasticity of the supply curve of agricultural output is less than that of nonagricultural inputs used in the food marketing industry) and $\sigma < 1$. These are case (b) conditions, suggesting that the farmer's share should increase in the presence of an exogenous increase in food demand, such as has been created for U.S. farm products by increasing export demand in recent years.

Equation (22) is distinct from, though closely related to, the effect of a change in N

[12] Pork does not seem to constitute a fixed proportions case since the 1.97 figure changes from year to year.

on P_x/P_a as given by equation (15). Equation (22) and the negative of equation (15) are the same if and only if $\sigma = 0$.[13]

Similar methods can be used to analyze the effects of supply as well as demand shifts. The right-hand-side elasticities are different in this case, being derived by differentiating with respect to W instead of N. The resulting equation is

$$(23)\quad E_{S_aW} = \frac{e_W e_a S_b(\eta - e_b)(\sigma - 1)}{D}.$$

The sign of equation (23) is determined by σ being less than, equal to, or greater than 1. If $\sigma < 1$, then a shift in the supply function of a which increases P_a, for example, a drought, will increase the farmer's share.

The economic sense of this result can be explained as follows. A drought reduces the food supply and hence tends to increase the price of food at both the farm and retail levels. The drought also makes agricultural output scarce relative to marketing inputs. The price of the latter rises by a smaller amount than does P_a. Therefore, the price of retail food rises by a smaller percentage than does the farm level price. If $\sigma \neq 0$ the ratio b/a will increase. The larger σ is, the more the demand for b will shift to the right, and consequently the larger the nonfarm input into food, which implies a smaller relative share of a in retail food costs. The elasticity of supply of b enters because although substitutability of b for a generates a shift in demand for b, the amount of additional b used depends also on its elasticity of supply to the marketing industry.

The preceding discussion is intended to bring out analytical differences between the farmer's share of the food dollar S_a and the price ratio P_a/P_x. The USDA publications on farm-retail price spreads use the share approach by adjusting P_a such that the units it pertains to are units of x. Whether data on S_a or P_a/P_x are more desirable depends, of course, on the use to which they are to be put.[14] The point of this discussion is that one has to be careful in interpreting farmer's share data in price ratio terms when $\sigma > 0$. For example, consider the historical data on price spreads in vegetable shortening. The farmer's share has decreased from 0.43 in 1947–49 to 0.30 in 1967–69 (Scott and Badger, p. 174), a decline of about 30%, while P_a/P_x has increased about 17% over the same period.[15] How is this possible? It is possible because while P_a (the price of soybeans) increased relative to P_x, other inputs have replaced soybeans to such an extent that S_a has actually fallen. Indeed, an estimate of σ can be obtained by dividing the percentage change S_a by the percentage change in P_x/P_a, since they differ only in being multiplied by $(\sigma - 1)$.[16] Thus, $\sigma - 1 \doteq \frac{-0.30}{-0.17}$ and $\sigma \doteq 2.8$. This is a very crude estimate and implicitly includes alternative farm products to soybeans in b. This may account for the high value of σ. That P_a/P_x increased while S_a decreased itself implies $\sigma > 1$.

Summary and Conclusion

Consistency with market equilibrium in a competitive food industry puts constraints on the pricing policies of food marketing firms. This paper has investigated the consequences of these constraints for the retail-farm price ratio and the farmer's share of the food dollar.

One implication of the results is that no simple markup pricing rule—a fixed percentage margin, a fixed absolute margin, or a combination of the two—can in general accurately depict the relationship between the farm and retail price. This is so because these prices move together in different ways depending on whether the events that cause the movement arise from a shift in retail demand, farm supply, or the supply of marketing inputs.

Some more specific results concerning the retail-farm price ratio are as follows. (*a*) Events that increase the demand for food will reduce the retail-farm price ratio (and percentage marketing margin) if marketing inputs are more elastic in supply than farm products, but increase P_x/P_a if marketing inputs are less elastic in supply than farm products. (*b*) Events that increase (decrease) the supply of farm products will increase (decrease) P_x/P_a.

[13] Because $E_{P_a/P_x,N} = -E_{P_x/P_a,N}$.

[14] Actually, it is hard to see that either one has much significance for agricultural policy or welfare issues. For most purposes it would seem more pertinent to look at relative farm income than relative prices or shares.

[15] For P_x, the data are the retail price figures of Scott and Badger (p. 174); for P_a, the price of soybeans as reported by the USDA.

[16] This is true whether the observed changes in S_a and P_x/P_a are generated by shifts on the supply side or the demand side, since both equations (15) and (22), and (16) and (23) differ only by the term $\sigma - 1$. The same result holds for elasticities with respect to T.

(*c*) Events that increase (decrease) the supply of marketing inputs will decrease (increase) P_x/P_a. (*d*) An effective price ceiling on retail food will reduce the price of farm products (unless the supply of farm products is perfectly elastic); P_x/P_a will increase (decrease) if the elasticity of supply of farm products is less (greater) than that of marketing inputs. (*e*) Supporting the price of farm products above the unrestricted market equilibrium level will reduce P_x/P_a.

All the preceding propositions can be derived by graphical methods like those of Tomek and Robinson (chap. 6) under the assumption of fixed proportions in food marketing ($\sigma = 0$). The advantage of the mathematical model is that it allows the treatment of the more general case in which $\sigma \geqslant 0$ and it provides quantifiable results.[17]

Other related results are as follows. (*f*) The farm level demand for agricultural products will be more or less elastic than the retail demand for food as $\sigma \lesseqgtr |\eta|$. (*g*) The percentage price spread is analytically distinct from the farmer's share of the food dollar, and the two will behave differently under changing market conditions unless $\sigma = 0$. If $\sigma = 1$, the farmer's share is constant. If $\sigma > 1$, an increase in the marketing margin will be accompanied by an increase in the farmer's share of the food dollar. Otherwise, lower margins go together with an increased farmer's share. (*h*) The elasticity of substitution between farm products and marketing inputs in producing retail food can be estimated by dividing observed changes in the farmer's share of the food dollar by observed changes in the ratio of farm to retail food prices.

Two limitations of the model are that it assumes competition and that it aggregates all marketing activities into one production function and all nonfarm marketing inputs into one quantity.

In relaxing the assumption of competition, although the constraints imposed by competition would disappear, the behavior of the marketing margin would still not be arbitrary. For example, the price behavior of a profit-maximizing retail food seller with monopoly power could be analyzed by replacing marginal product times input price by marginal revenue product in equations (3) and (4). Then elasticities such as equations (15), (16), and (17) could be solved from the new system. Similarly, monopsony in the purchase of a farm product could be introduced by replacing input price by marginal factor cost.

The aggregation problem is serious in some contexts but negligible in others. It is most serious when the changes being considered have large effects on the relative prices of different marketing inputs. In order to examine particular relative price changes within the set of marketing inputs, a three-input model along the lines of Welch might prove a useful alternative approach.

A possible further extension would be to add separate production functions and profit-maximization equations for different marketing activities. This approach would provide more realism for investigating certain problems but would be costly in terms of complexity and intelligibility, and it seems doubtful whether it would yield any basic changes in the results from the simple model of this paper as expressed in propositions (*a*) through (*h*). But this remains to be seen.

Finally, it might prove interesting to investigate the consequences of technical progress in the marketing industry by introducing exogenous shifters of equation (1). This also could follow the approach of Welch.

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[17] In the strict fixed proportions case, marginal products cannot be calculated and the original system of derivatives breaks down. The correct procedure to get quantitative predictions in this case is to take the limit of equations (15) to (23) as $\sigma \rightarrow 0$.

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Appendix

Mathematical Derivations

Derivation of $E_{P_x/P_a,N}$. Starting with equations (9) to (11), first convert all derivatives into elasticities. For example, from equation (5),

$$g_b = \frac{dP_b}{db}.$$

Multiplying by b/b and P_b/P_b,

$$g_b = \left(\frac{dP_b}{db} \cdot \frac{b}{P_b}\right) \frac{P_b}{b}$$
$$= \frac{1}{e_b} \frac{P_b}{b},$$

where e_b is the own-price elasticity of supply to the industry. Second, use the assumption of constant returns to scale to eliminate all second partials (Allen, p. 343), since

$$f_{ab} = \frac{f_a f_b}{\sigma x}$$

and

$$f_{aa} = \frac{b}{a} \cdot \frac{f_a f_b}{\sigma x}.$$

Third, eliminate f_a and f_b wherever they appear by substituting P_a/P_x and P_b/P_x from equations (3) and (4). Making these substitutions and rearranging terms yields equations (12) to (14).

From the system of equations (12)–(14), first find E_{P_xN} by means of Cramer's Rule. Expanding the appropriate determinants,

$$E_{P_xN} = \eta_N \left(\frac{S_b S_a}{\sigma^2} + \frac{S_b}{\sigma e_b} + \frac{S_a}{\sigma e_a} + \frac{1}{e_a e_b} - \frac{S_b S_a}{\sigma^2}\right) \Big/$$
$$-\eta \left(\frac{S_b}{\sigma e_b} + \frac{S_a}{\sigma e_a} + \frac{1}{e_a e_b}\right) + \left(\frac{2S_a S_b}{\sigma} + \frac{S_a^2}{\sigma} + \frac{S_b^2}{\sigma}\right)$$
$$+ \frac{S_a}{e_b} + \frac{S_b}{e_a}.$$

The second bracketed term of the denominator equals $1/\sigma$ (since $S_b = 1 - S_a$). Multiplying the numerator and denominator by $\sigma e_a e_b$ yields

(A.1) $$E_{P_xN} = \frac{\eta_N(S_b e_a + S_a e_b + \sigma)}{-\eta(S_b e_a + S_a e_b + \sigma) + e_a e_b + \sigma(S_a e_a + S_b e_b)}.$$

The denominator of this expression, in the text, and henceforth in this appendix is denoted by D.

Next, from the same system of equations, solve for E_{aN}.

(A.2) $$E_{aN} = \frac{\eta_N e_a(e_b + \sigma)}{D}.$$

To get from E_{aN} to E_{P_aN}, divide E_{aN} by e_a, since

(A.3) $$E_{aN}/e_a = \left(\frac{da}{dN} \cdot \frac{N}{a}\right) \Big/ \left(\frac{da}{dP_a} \cdot \frac{P_a}{a}\right),$$
$$= \frac{dP_a}{dN} \cdot \frac{N}{P_a} = E_{P_aN}.$$

Finally, to get $E_{P_x/P_a,N}$, note that

(A.4) $$E_{P_x/P_a,N} = \frac{d(P_x/P_a)}{dN} \cdot \frac{N}{P_x/P_a}$$
$$= \frac{P_a dP_x - P_x dP_a}{P_a^2\, dN} \cdot \frac{NP_a}{P_x}$$
$$= \frac{NP_a^2 dP_x}{P_a^2 P_x dN} - \frac{NP_x dP_a}{P_x P_a dN}$$
$$= E_{P_xN} - E_{P_aN}.$$

Substituting (A.1), (A.2), and (A.3) into (A.4) yields

(A.5) $$E_{P_x/P_a,N} = \frac{\eta_N S_b(e_a - e_b)}{D},$$

which is text equation (15).

Derivation of $E_{P_x/P_a,W}$. After making the changes in equations (12) – (14) described in the text, solve for

(A.6) $$E_{P_xW} = \frac{e_W e_a S_a(e_b + \sigma)}{D},$$

and

(A.7) $$E_{a,W} = \frac{e_W e_a(\eta\sigma + e_b(S_a\eta - S_b\sigma))}{D}.$$

To get from E_{aW} to E_{P_aW}, it is again necessary to divide E_{aW} by the elasticity of a with respect to P_a. But the appropriate elasticity is the elasticity of demand for a, not the supply elasticity as was used in equation (A.3). In the preceding section the demand for x was shifting, which generated movement along the supply curve of a. In this section the supply curve of a is shifting, which generates movement along the demand curve for a. Therefore, to get E_{P_aW}, divide E_{aW} by E_{aP_a} where E_{aP_a} is the elasticity of demand for a. Using the formula for E_{aP_a} given as text equation (21) yields

$$\text{(A.8)} \qquad E_{P_aW} = E_{aW}/E_{aP_a} = \frac{e_We_a(e_b + S_a\sigma - S_b\eta)}{D}.$$

Subtracting E_{P_aW} from E_{P_xW} to get $E_{P_x/P_a,W}$ yields

$$\text{(A.9)} \qquad E_{P_x/P_a,W} = \frac{e_We_aS_b(\eta - e_b)}{D},$$

which is text equation (16).

Derivation of $E_{P_xP_a}$ when price changes are caused by a shift in product demand. This elasticity can be obtained by dividing E_{P_xN}/E_{P_aN}. Using equations (A.1), (A.2), and (A.3),

$$\text{(A.10)} \qquad E_{P_xP_a} = \frac{\eta_N(S_be_a + S_ae_b + \sigma)}{D} \cdot \frac{D}{\eta_N(e_b + \sigma)} = \frac{S_be_a + S_ae_b + \sigma}{e_b + \sigma}.$$

This is the reciprocal of text equation (18).

Derivation of $E_{P_xP_a}$ when price changes are caused by a shift in the supply curve of a. This elasticity can be obtained by dividing (A.6) by (A.8),

$$\text{(A.11)} \qquad E_{P_xP_a} = \frac{e_We_aS_a(e_b + \sigma)}{D} \cdot \frac{D}{e_We_a(e_b + S_a\sigma - S_b\eta)} = \frac{S_a(e_b + \sigma)}{e_b + S_a\sigma - S_b\eta},$$

which is text equation (19).

Derivation of E_{S_aN}. First consider the total differential of S_a

$$dS_a = \frac{xP_x(adP_a + P_ada) - aP_a(xdP_x + P_xdx)}{(xP_x)^2}.$$

Dividing through by a change in population, dN, to get an exogenous influence on the system from the demand side, yields (after converting to elasticities)

$$\text{(A.12)} \qquad E_{S_aN} = E_{P_aN} + E_{aN} - E_{P_xN} - E_{xN}.$$

These elasticities were all discussed earlier except for E_{xN}. Using the facts that $f_a = P_a/P_x$, $f_b = P_b/P_x$, and $dx = f_ada + f_bdb$, this elasticity is analyzed as follows:

$$\text{(A.13)} \qquad E_{xN} = \frac{dx}{dN} \cdot \frac{N}{x} = f_a \frac{da}{dN} \cdot \frac{N}{x} + f_b \frac{db}{dN} \cdot \frac{N}{x} = \frac{P_a}{P_x} \cdot \frac{da}{dN} \cdot \frac{N}{x} \cdot \frac{a}{a} + \frac{P_b}{P_x} \cdot \frac{db}{dN} \cdot \frac{N}{x} \cdot \frac{b}{b} = S_aE_{aN} + S_bE_{bN}.$$

Substituting equation (A.13) into equation (A.12) yields

$$\text{(A.14)} \qquad E_{S_aN} = E_{P_aN} - E_{P_xN} + S_b(E_{aN} - E_{bN}).$$

The new elasticity in (A.14) is E_{bN}. It is the third variable in the system, equations (12) to (14), which has already been solved for E_{aN} and E_{P_xN}. Returning to the equation system for the first part of the appendix.

$$\text{(A.15)} \qquad E_{bN} = \frac{\eta_Ne_b(e_a + \sigma)}{D}.$$

Combining equations (A.3), (A.1), (A.2), and (A.15) according to equation (A.14) yields

$$\text{(A.16)} \qquad E_{S_aN} = \frac{\eta_N}{D}(e_b + \sigma - S_be_a - \sigma + S_be_ae_b + S_be_a\sigma - S_be_be_a - S_be_b\sigma) = \frac{\eta_N}{D}(S_b(e_a - e_b)(\sigma - 1)),$$

which is text equation (22).

Derivation of E_{S_aW}. Again, all the elasticities are available except E_{bW}:

$$\text{(A.17)} \qquad E_{bW} = \frac{e_We_ae_bS_a(\eta + \sigma)}{D}.$$

Combining equations (A.8), (A.6), (A.7), and (A.17) according to equation (A.14) with W replacing N yields

$$E_{S_aW} = \frac{e_We_a}{D}[e_b + S_a\sigma - S_b\eta - S_ae_b - S_a\sigma + S_b\eta\sigma + S_b(S_ae_b\eta - S_be_b\sigma - S_ae_b\eta - S_ae_b\sigma)] = \frac{e_We_aS_b}{D}[(\eta - e_b)(\sigma - 1)],$$

which is text equation (23).

Hedging and Income Stability: Concepts, Implications, and an Example

Anne E. Peck

The variability in prices often of concern to producers is that which occurs after a production decision has been made but before the commodity can be marketed. A portfolio-type analysis is used to formalize this problem and describe the role futures markets can perform in facilitating the management of this risk. Data from the egg market are used to illustrate hedging opportunities for an egg producer. The results show that hedging a substantial percentage of expected production can significantly reduce a producer's exposure to the risk. Additionally, a total hedging scheme performed nearly as well as an optimal scheme.

Key words: income stability, producer hedging, futures markets, portfolio analysis.

The application of portfolio analysis to hedging problems is not new. Recently, Rutledge has shown its usefulness as a pedagogic device, capable of integrating the often conflicting views of hedger motivation into a consistent framework. Hedgers consider both expected returns and risks in deciding how much of a cash position to cover in futures contracts. Other writers have focused explicitly on the question of producer hedging (McKinnon; Ward and Fletcher). These analyses rely on traditional measures of expected returns and risk in an uncertain world; they essentially depend upon the mean and variance of a series of past years' prices to determine an optimal portfolio.

Reliance on these measures imposes a long-run perspective on their analyses. This, in turn, leads directly to their major conclusions. In general, hedging expected production in the relevant new crop future will stabilize producer's income only if the year-to-year variation in futures prices is less than that in cash prices. McKinnon suggested the importance of providing a stable, distant future to stabilize producer incomes. If a producer could sell his annual production forward at an essentially constant (year-to-year) price, then his income would be stabilized.

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The necessity for a constant forward price comes directly from having used the variance of annual forward prices as the measure of risk. This theoretical result has been confirmed empirically by several investigators. Tomek and Gray show that production period hedging will stabilize incomes for potato producers since the planting time quote of the new crop future is virtually constant from year to year. A similar hedging routine in corn or soybeans will do little to stabilize incomes, since the planting time quotes of the new crop futures for these commodities are as variable as the harvest prices. Heifner investigated minimum-risk hedging strategies for cattle feeders. His results suggest there may be some reduction in income variation if feeders hedge some of their expected output.

For most commodities, interyear variation in futures prices is as great as that in cash prices. Hence, reduction in income variation using a routine hedging procedure is apt to be small by these measures. These results seem puzzling in the light of the apparent usefulness of futures markets in the grain trade. The difficulty lies in using the traditional measures of return and risk, imposing a long-run view on the criterion of usefulness. While the past is not necessarily a bad guide to the future, these measures do not reflect the uncertainty or risk actually confronting producers. Futures markets operate with an essentially short-run horizon. Contracts are traded for at most a year in advance of their expiration, often for shorter periods. This is long enough to be as useful to producers as it is to the

commercial trade. But, for most commodities, it is certainly not long enough to stabilize incomes in the sense used by the above authors.

To provide producers with a market to facilitate management of risk, forward trading is necessary over that period when the financial results of their production decisions are uncertain, between the planting decision and the actual harvest. For instance, corn is planted in May but not harvested until October and November. To make a production decision in May, the producer must form some notion of an expected price. After planting, the only relevant price variability is that which makes his forecast differ from the actual harvest price. Year-to-year price variability is not necessarily bad. It reflects, at least in part, a changing mix of products required by continually changing, relative demands. For the producer who is able to vary his production accordingly, relatively little income destabilization may be occasioned by interyear price variability. The crucial variance remaining, however, is that which surrounds the accuracy of the producers' forecasts, the mean squared error of the forecasts. The remainder of this paper explores the economic implications of producer hedging from this viewpoint. First, the portfolio model is briefly described. Then, hedging routines using these criteria are derived and evaluated for an egg producer.

The Portfolio Analysis

Applying the portfolio analysis to this hedging problem provides some interesting differences with previous approaches. Assume, for simplicity, that the production decision is made, and the output Q is known.[1] This production decision, made in month $t - i$, will mature in month t, where i is the gestation period. The decision was based upon an expected price, P^*_{t-i}, where the subscript refers to when the expectation was held and an asterisk denotes an expectation. Let σ_p^2 be a measure of the uncertainty surrounding that forecast. If, for instance, a single-equation forecasting model is used, then σ_p^2 would be the forecast variance of the model. Alternatively, if these are subjective or point forecasts, then their mean squared error over past periods may be used as an estimate of σ_p^2. The essential difference with the traditional uses of portfolio analysis is recognizing that there are often better forecasts than the average of past returns. Further, the only portion of the variance (about the average return) that is relevant to the decision maker is that which has been left unexplained.[2]

With the further assumption that costs are essentially fixed at the decision time and hence may be neglected, the expected returns may be derived, along with their mean squared error:

$$E(R) = E(QP_t) = QP^*_{t-i},$$

and

$$MSE(R) = E(QP_t - E(QP_t))^2 = Q^2[E(P_t - P^*_{t-i})^2] = Q^2 \sigma_p^2.$$

This is the variability which the producer cannot control through production adjustment, given that production is fixed. Clearly, a producer could reduce his risk to zero by deciding not to produce. But, having made a production decision, the producer confronts the risk that his forecast may not be accurate. In the presence of an active futures market, the producer may sell a part or all of his production before the actual marketing period. In this case, his expected return additionally depends upon the expected futures price change. Let F_{t-i} be the quote in period $t - i$ of the futures contract maturing in period t. As a first approximation, assume that the cash price and the futures price coincide in the delivery period; that is, the expected expiration price of the futures contract maturing in period t, F^*_{t-i}, is assumed equal to the cash price expected to exist in that same period, P^*_{t-i}, both expectations held in the same month $t - i$. Then, the expected return from holding a futures contract, the expected futures price change, is

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[1] The analysis developed below uses as a model the situation found more nearly in cattle or egg production rather than in the grains. Once feeders or laying hens are purchased, the output is essentially fixed. In the grains, output is not so clearly fixed, and its subsequent variance must be considered. Considering that additional factor would only complicate the analysis unnecessarily.

[2] Fried provides a theoretical development of this point using a single-equation, ordinary least-squares forecasting model. "The explained variation provides a means of evaluating the change in expected returns from period to period but does not affect the variation about this changing expected value and consequently does not affect the risk associated with nonattainment of that expected value. The variance of the disturbance term [from the OLS equation], on the other hand, does not contribute anything to changes in the expected returns since, by definition, it represents random occurrences that cannot be specified except by a probability distribution with constant mean" (p. 542). Logan and Bullock apply a similar approach in a decision-making model for speculators.

$$E(F_{t-i} - F_t) = F_{t-i} - E(F_t) = F_{t-i} - P^*_{t-i}.$$

The assumption that cash and futures prices converge in the delivery month obviates the need for a second forecast even though both a cash and a futures market are considered in the analysis. The forecast, P^*_{t-i}, is a price level, cash as well as futures, forecast.[3]

Let Q_H be the amount to be hedged. Then, the new expected return and its variance may be calculated:

$$E(R) = E(QP_t + Q_H(F_{t-i} - F_t)) \\ = (Q - Q_H)\,P^*_{t-i} + Q_H\,F_{t-i},$$

and

$$MSE(R) = E[R - E(R)]^2 = (Q - Q_H)^2\,\sigma_p^{\,2}.$$

If cash and futures prices coincide in the delivery month, then the producer could eliminate all his uncertainty about expected returns caused by using a forecast price in his production decision. This could be accomplished by hedging all of his output. Eliminating this residual uncertainty may come at some cost (or gain) if the current futures quote F_{t-i} does not equal its forecasted expiration value P^*_{t-i}.

This analysis, simplified by assuming convergence, illustrates the potential futures markets may have for stabilizing producer revenues. The series of futures quotes at which the hedge is placed may well be as variable as the actual cash price series. The futures market will still provide a means for the producer to control the uncertainty in his revenues. The analysis can be generalized by relaxing the assumption that cash and futures prices converge in the delivery period. At a minimum, the cash and futures prices in a delivery month would be expected to differ by the physical costs of delivery.

The difference between these two prices in the delivery period, the basis, is the new variable which must be considered. This differs from previous analyses which used expected cash and expected expiration prices as the two forecasts necessitated by the presence of a futures market. This approach recognizes that there is really only one price level involved. The basis generally is much more stable than the price level and hence more reliably predicted. More interesting is the ease with which the analysis may be identified with the individual producer and his particular location. A hedger presumably has no intention to deliver. In reality, actual delivery from a given area to an exchange-approved location may be so difficult that it precludes even intending to deliver. This situation is easily handled by including the basis price. Finally, using the basis price in this analysis focuses more clearly on the rationale of hedging, to benefit from the relative movements between the two prices.

Let B^*_{t-i} be the basis expected to exist in delivery month t, the expectation held in period $t - i$; B_t is then the actual basis in delivery month t $(F_t - P_t)$. Further, let $\sigma_b^{\,2}$ be a measure of the forecast variance; one estimate of this would be the mean squared error. Finally, let σ_{pb} measure the covariance between the cash and basis price forecast errors. The expected returns and their mean squared errors may now be derived:[4]

$$E(R) = E[QP_t + Q_H\,(F_{t-i} - (P_t + B_t))] \\ = QP^*_{t-i} + Q_H\,(F_{t-i} - P^*_{t-i} - B^*_{t-i}),$$

and

$$MSE(R) = E[R - E(R)]^2 \\ = (Q - Q_H)^2\,\sigma_p^{\,2} + Q_H^{\,2}\,\sigma_b^{\,2} - 2Q_H\,(Q - Q_h)\,\sigma_{pb}.$$

With the more general formulation, risk cannot be eliminated so readily. The risk in returns from a completely hedged position will be proportional to the error in the basic forecast. The Markowitz approach provides the traditional formulation of the decision criterion when both expected returns and risk are important:

$$\max\ \psi = E(R) + \lambda MSE(R).$$

The parameter λ, the risk parameter, represents an individual's subjective weighting of expected return relative to the risk associated with achieving that return. Individuals are assumed to be risk averse, which implies λ is negative; that is, with two portfolios having equal expected returns, the one with the smaller variance would be chosen. From the usual

[3] The question of bias has been avoided. It may well be that the futures quote F_{t-i} is the best available, unbiased predictor. In this case, $P^*_{t-i} = F^*_{t-i}$, and the expected returns are unaffected by the hedging decision. The above formulation admits the possibility that there may be better forecasts of subsequent cash prices than the current futures quote. Recent evidence from the market for Maine potatoes (Gray) and for live cattle (Leuthold) suggest there may in fact be better forecasts in some markets.

[4] Given the definitional relationship amongst cash, futures, and basis prices, the expected returns and their mean squared error could be expressed as functions of cash and futures price forecasts and their errors. However, the relative stability of the basis suggests that it could be predicted most reliably. The present approach exploits that stability.

first-order conditions, the optimal hedge may be derived:[5]

$$Q_H = Q \frac{\sigma_p^2 + \sigma_{pb}}{\sigma_p^2 + \sigma_b^2 + 2\sigma_{pb}} - \frac{F_{t-i} - P^*_{t-i} - B^*_{t-i}}{2\lambda\,(\sigma_p^2 + \sigma_b^2 + 2\sigma_{pb})}.$$

Given a production decision, the optimal hedge is a function of both expected returns and the error structure of and among the forecasts. Additionally, it may depend upon the unknown, subjective risk parameter, λ. Note, however, that if the second term in the above expression can be neglected, then the optimal hedge is proportional to the amount to be produced. This factor of proportionality is composed only of the measures of the forecast errors. The second term probably can be ignored for most purposes. The numerator is the expected futures price change, not likely to be large. This is then to be divided by a combination of squared forecast errors. Hence, unless the risk parameter λ is very small, this term is likely to be inconsequential; that is, unless risk does not matter, it is likely that the optimal hedge will be determined by the squared errors in the forecasts, a percentage of the given production.

Hedging Strategies in the Egg Market

Using the preceding formulation of the portfolio model, the intent is to derive a sequence of optimal hedging positions that could have been adopted by a producer. These positions must be based upon information that was available at the time the decision was to have been made. Then, *ex post,* their effects on producer returns can be evaluated. This approach requires successive forecasts of the expected price and of the expected basis during delivery months. This requirement led to selecting the egg market for the analysis. Two series of cash price forecasts were available, forecasts which had been made available to egg producers both within and outside of Indiana. Hence, they were forecasts that could have been used by producers in making both production and hedging decisions.

The series of forecasted prices which were available for this analysis were forecasts of the Urner-Barry price quotation for fancy large shell eggs in New York.[6] This quotation is assumed to be the relevant cash market price. Equivalently, producers are assumed to price their output from the Urner-Barry quotation. Either they are using that price directly, or, given their location, a fixed differential from the Urner-Barry quote is used. While this appears to be a somewhat restrictive assumption, its relaxation only would involve acquiring firm-specific data.

Shell eggs are traded on the Chicago Mercantile Exchange. There are twelve contracts each year, one with delivery in every month. Some contracts are actively traded less than six months prior to expiration. Others, for example, the September contract, are active for at least a year prior to expiration. This creates a problem for a producer who wishes to hedge sequentially the entire production expected from a given decision. Eggs will be produced continuously from approximately the sixth to the twentieth month after that decision. Obviously, the producer cannot hedge this entire output sequentially. At least two alternatives are possible.

A producer could sequentially hedge his expected production as far out as possible. The remaining expected output could then be hedged in the most distant future. As more distant futures become active, he could roll forward the appropriate portion of that position. Alternatively, the futures market may be viewed as a marketing tool. The question is then how much of any expected production to sell forward. Being unable to sell the entire production forward is less bothersome with this approach. Any time horizon may be considered relevant. For these reasons, the latter approach is adopted here.

The basis remains to be defined. The futures contracts currently call for an in-plant delivery, with plant location in the Chicago area being par delivery. Deliveries are possible virtually anywhere, at exchange-approved discounts to the contract price. For instance, delivery from a New York location involves a discount of 60¢ to 90¢. This differential is not, however, the relevant basis. The basis must

[5] The second-order condition is:

$$\frac{d^2\psi}{d\,Q_H^2} = \lambda\,(\sigma_p^2 + \sigma_b^2 + 2\sigma_{pb}).$$

A maximum is ensured since $-\infty < \lambda \leq 0$, since hedgers are assumed to be risk averse.

[6] Urner-Barry is a market news service which daily reports a representative, New York egg price. "Our present quotation on large whites is a meld of the trading at all levels. . . . [It] coincides with the average paying price for truckload lots of top quality cartoned large whites delivered warehouse into the northeastern metropolitan area" (Urner).

be the market-determined price differential between an expiring future and the cash price. The average difference between an expiring future and the Urner-Barry quotes during the delivery month is taken as the measure of the basis. The specific Urner-Barry quotation used in this analysis was that for fancy large eggs. It corresponds most nearly to the contract grade (90% grade A or better).

As noted earlier, the egg market was selected for this analysis primarily because series of price forecasts were already available. As a part of the research and extension work in the poultry marketing area, a single-equation model was built to help in forecasting egg prices. The data used in the estimation of the model's parameters were updated periodically so no one model was used continuously over a long period. Each month, the model was used to forecast the Urner-Barry, average monthly price for each of the next twelve months. The data used to make the forecasts came from the monthly *Eggs, Chickens, and Turkeys* reports of the U.S. Department of Agriculture. Additionally, a similar series of forecasts, determined subjectively on the basis of that same information, were also made each month. Records of both forecast series were kept. The interesting feature of these forecasts is that they were available to the poultry industry in Indiana and elsewhere. Thus, they are forecasts which could have been used to make production, marketing, and hedging decisions.

In addition to these two forecasts, a forecast based upon futures quotes was derived. It was simply the current quote for a specified delivery minus the expected basis in the delivery month. The futures price is the one on or nearest the twentieth of the month, after the information available in *Eggs, Chickens, and Turkeys* is released. The basis forecast, used here and as a separate variable in the model, was the average delivery basis in the preceding twelve months.[7]

Summary measures of the performance of these forecasts are presented in table 1. The results are arranged by the length of the forecast interval, from one to five months ahead. In addition to the traditional measures of performance, the mean and the standard error, the table includes the average forecast error and the positive root of the mean squared error. The first forecasts were for the June 1971 Urner-Barry quote; the last forecasts were for December 1973. Since forecasts for each horizon were made on a monthly basis, there are essentially thirty-one observations for each horizon.[8] Over this period, the average Urner-Barry quote was 45.84¢ per dozen with a standard error of 14.25¢. All the forecasts had similar mean values. The standard errors of the futures-derived and the point forecasts were also of a similar magnitude. The forecast from the regression model was much less variable in this sense.

The average forecast errors of all three forecasts were very small, revealing no significant tendency to over- or underestimate the cash price. The interesting differences appear in the root mean squared errors, the measure of uncertainty to be used in the portfolio model. The forecast which was most stable in the standard error sense, the regression forecast, was least reliable in the squared error sense. Conversely, the most variable forecast, the futures forecast, was generally the most reliable forecast in that sense. Clearly, the choice of a measure of uncertainty will make an important difference in the apparent usefulness of a hedging routine derived from these measures.

Table 1 reports the mean squared errors of the forecasts over the whole period. To make the portfolio model operational, estimates of these are needed that would have been available at the time the hedge was placed. The estimates of σ_p^2 are the mean of the squared forecast errors over the twelve months preceding the month in which the hedging decision is to be made. Separate estimates are made for each forecast horizon each month. As noted earlier, the basis forecast is itself an average of the twelve preceding months' actual delivery basis. This is the forecast of the basis for the next five delivery months; each month a new forecast is calculated. The mean squared error of these forecasts over the preceding twelve months forms the estimate of

[7] Specifications for par delivery on futures contracts were changed in March 1972. Prior to that date, par delivery was by warehouse receipt with a 1¢ discount for in-plant delivery. For basis forecasts for the first twelve months after this change, which required some data from the earlier period, the old basis was used, adjusted by 1¢.

[8] For the forecast series derived from the future quotes, this is not quite true. Even with the analysis restricted to five months ahead, there were discontinuities in the series of futures quotes for contracts maturing in five months. For example, of the thirty-one contracts (one for each month) only twenty-seven were traded four months before that delivery. For this horizon, there would only be twenty-seven observations.

Table 1. Performance of the Three Forecasts, June 1971–December 1973

	Forecast Horizon				
	1	2	3	4	5
Regression forecast					
mean	43.02	42.80	42.98	42.94	42.84
standard error	7.22	5.92	6.03	5.97	6.10
average forecast error	1.22	1.44	1.27	1.30	1.40
root mean squared error	10.04	11.03	11.43	11.41	11.83
Point forecast					
mean	45.47	45.34	45.10	44.40	43.79
standard error	13.13	12.62	12.32	11.26	9.86
average forecast error	−1.23	−1.10	−0.85	−0.16	0.45
root mean squared error	4.16	5.88	7.55	8.86	9.29
Futures forecast					
mean	44.86	46.02	47.47	47.76	47.39
standard error	13.93	13.05	12.89	13.02	19.13
average forecast error	−0.62	−1.78	−2.01	−1.73	0.06
root mean squared error	3.16	6.58	7.78	8.59	8.88

Note: See text for a description of the forecasts. The measures are:

$$\text{mean} = (\sum_n P^*_{t-i})/n = \overline{P},$$

$$\text{standard error} = [(\sum_n (P^*_{t-i} - \overline{P})^2)/(n-1)]^{1/2},$$

$$\text{average forecast error} = (\sum_n (P_t - P^*_{t-i}))/n,$$

$$\text{root mean squared error} = [(\sum_n (P_t - P^*_{t-i})^2/n]^{1/2},$$

where P^*_{t-i} is the forecast for month t in month $t-i$ (i is the horizon of the forecast) and P_t is the Urner-Barry quote for fancy large eggs on the first business day in month t. All figures represent cents per dozen.

σ_b^2.[9] A minimum of twenty-nine months of data is required for these estimates, twenty-four months in the forecast and its error and a possible five-month horizon. Thus, though the forecast and futures data are available from January 1969, the actual analysis does not begin until June 1971. Finally, σ_{pb} is the product of the forecast errors in the cash and basis forecasts, again averaged over the preceding twelve months.

With these estimates, the producer can calculate an optimal hedge, given his production. In any month, for instance January, a producer has available forecasts for the prices expected in the next five months, February through June. The actual production decision has been made several months ago; the question is whether to hedge the egg production which is expected over the coming months. The producer is also aware that his forecasts are subject to uncertainty. Generally, the longer the forecast period, the less reliable the forecast. Using their performance over the past year, he estimates the uncertainty he can expect. Further, he assumes that last year's average delivery basis will exist in each of the coming months, again, with estimable error. With this information, the producer makes his decisions about hedging in each of the approaching delivery months.

Every month, the producer decides his hedging strategy in each of the five nearest futures contracts, always updating the estimated variables. This routine implies there will be five positions recommended in each future, one from each of the five forecast horizons. Clearly, a dynamic model is possible, allowing the producer to adjust an initial position as new forecasts and performance data become available. For purposes here, however, a static analysis suffices. A producer is not allowed to change a position, once taken. Equivalently, the producer is seen to have access only to forecasts of a fixed horizon, one to five months; the hedging routines compare the results of having the forecasts available with different horizons. Admittedly, this is a restrictive assumption. It permits direct evaluation; any reduction in the measured risk

[9] Specifically, the basis expected in month t, which is i months ahead is

$$B^*_{t-i} = \left(\sum_{j=t-i-11}^{t-i} B_j\right) \Big/ 12.$$

The estimate of σ_b^2 is

$$\sigma_b^2 = \left[\sum_{j=t-i-11}^{t-i} (B_j - B^*_{j-i})^2\right] \Big/ 12.$$

will be attributable to the one portfolio decision. Thus, while not a realistic assumption, its relaxation would only complicate the evaluation.

In the theoretical development, the hedging decisions were seen to depend also on the subjective risk parameter, λ. This is no problem for the individual producer, since it is his evaluation of risk relative to expected returns. It was suggested that it might not be a problem here. Over a wide range of values, the parameter might not affect the hedging decision. Theoretically, the parameter may be any negative number. Iterating over a range of values, the recommended hedges were found to be identical for all values of λ less than minus one. This simplifies reporting the results. The main results to be discussed here will be those for which the positions are stable. Results as the risk parameter approaches zero are also presented and their differences are briefly noted.[10]

Average hedges, as a percent of production, are reported in table 2. These are the means of the positions determined from the portfolio model for each forecast series and each forecast horizon, averaged over approximately thirty-one optimal hedges. Standard errors are also presented, indicating the variability in the positions over this period. Variation results since the estimates of the error structure are continually revised. The lower half of the table summarizes the hedge positions as the risk parameter decreases, that is, as the expected futures return receives increasing weight.

As is clear from table 2, the producer generally hedges less than his total expected production. An optimal hedge could have been speculative, either a long futures position or a short position greater than expected production. The model imposed no constraints. Though there were instances where a larger short position was optimal, this was not true generally. The positions did not differ consistently among forecasts or among forecast horizons. They were consistently 75% to 95% of production. When the risk parameter was allowed to approach zero, greater instability in the positions results. The averages appear not much different than before, but the standard errors become much larger.

[10] Note that the optimal hedge is invariant to the risk parameter λ when the forecast based on the current futures quote is used. Using this forecast implicitly assumes that the expected futures return is zero. The futures quote (adjusted for the expected delivery basis) is the best available forecast.

Ex ante, these positions are optimal; they result from maximizing expected returns subject to estimated risks. Did they in fact stabilize producer revenues in the sense of reducing those risks? The evaluation of these strategies and their effects on revenues and their variability is summarized in tables 3 and 4. Table 3 summarizes the effects of strategies when the expected futures return is not important, that is, when $-\infty < \lambda \leq -1$. Table 4 summarizes the results when the expected futures return becomes increasingly important. The forecast performance data, summarized in table 1, provide the basis to which these results should be compared. The performance data are the variations the unhedged producer confronts.

The average, unhedged return over the period analyzed was 45.84¢ per dozen with a standard error over that period of 14.25¢ per dozen. From table 3, the average returns increased using any hedging strategy regardless of the forecast used or its time horizon. Further, the returns tended to be larger the earlier the hedge was placed. This suggests that futures prices tended to overestimate their final expiration values during this period. A separate test for bias in the futures prices revealed this was not a significant tendency, however.[11] What is striking in these results is the important reduction in actual risk with the optimal hedging strategies. This reduction occurred for each of the three forecasts over all hedging horizons. Virtually all the reported squared errors were in the 2¢ to 2.5¢ per dozen range. This compares with the 4¢ to 12¢ per dozen range of the squared error measures reported in table 1.

The measures of risk which have been reported in these tables are the square roots of the measures actually used in the portfolio derivations. Thus, the squared errors of the optimal hedging strategies represent a four to twenty-five fold reduction in measured risk. This reduction occurred even though the standard errors of the returns remained virtually unchanged as between a hedged and an unhedged position. The standard errors reported here probably overstate the variation in returns, since they omit all quantity changes over the period. Presumably a producer adjusted his production to changing price expectations represented by the various price fore-

[11] Holding a short position in every futures contract from June 1971 to December 1973 for periods of up to five months produced no significant profits using a t-test for significance.

Table 2. Means and Standard Deviations of the Optimal Hedging Positions, June 1971–December 1973

Average percentage of production to be hedged assuming the expected futures return is inconsequential ($-\infty < \lambda \leq -1$)

	Horizon of Hedge 1	2	3	4	5
Using regression forecast	83.33	87.35	88.23	86.50	84.74
	(14.20)	(7.35)	(6.86)	(8.19)	(9.27)
Using point forecast	76.06	81.58	87.16	87.42	86.57
	(7.22)	(6.36)	(6.12)	(6.43)	(6.97)
Using futures forecast	57.81	78.28	83.12	82.31	84.80
	(14.67)	(5.38)	(7.90)	(7.12)	(8.06)

Average percentage of production to be hedged as the subjective weighting of risk approaches zero[a]

	1	2	3	4	5
Using regression forecast					
with $\lambda = -0.1$	83.09	87.33	88.24	86.55	84.78
	(14.93)	(7.43)	(6.98)	(8.33)	(9.46)
with $\lambda = -0.01$	80.67	87.09	88.37	86.97	85.11
	(27.86)	(11.22)	(10.38)	(11.52)	(15.48)
with $\lambda = -0.001$	65.53	84.70	89.60	91.20	88.46
	(200.90)	(81.98)	(70.68)	(69.25)	(113.30)
Using point forecast					
with $\lambda = -0.1$	72.84	81.68	87.29	87.60	86.67
	(7.23)	(6.21)	(6.01)	(6.43)	(6.97)
with $\lambda = -0.01$	70.71	82.71	88.69	89.36	87.73
	(13.29)	(7.26)	(6.81)	(8.05)	(8.52)
with $\lambda = -0.001$	49.35	93.04	102.60	107.00	98.34
	(117.30)	(59.32)	(50.31)	(51.52)	(52.30)

Note: Standard deviations are in parentheses.
[a] The positions change with the parameter λ only when the regression and point forecasts are used. The positions derived when the futures forecast is used are invariant with respect to the risk parameter. See footnote 10 in the text.

casts. Though the overall variation was unaffected, the hedging strategies proved to be a useful tool in reducing the risk confronting a producer.

Table 3 also reports results from a total hedging scheme. In this situation, the producer is assumed to always hedge his total expected production. Again, the results are

Table 3. Performance Measures of the Hedging Schemes Assuming the Expected Futures Return is Inconsequential ($-\infty < \lambda \leq 1$)

	Horizon of Hedge 1	2	3	4	5
Using regression forecast					
mean return	44.90	46.11	47.52	47.85	47.80
standard error	13.69	12.85	12.57	12.99	11.35
root mean squared error	2.50	2.25	2.21	2.45	2.63
Using point forecast					
mean return	44.93	46.09	47.53	47.95	47.97
standard error	13.64	12.72	12.46	12.90	11.19
root mean squared error	1.94	2.03	2.18	2.35	2.47
Using futures forecast					
mean return	44.74	45.99	47.47	48.00	48.26
standard error	13.78	12.87	12.55	12.98	11.05
root mean squared error	2.08	2.03	2.30	2.32	2.15
Using a total hedging strategy					
mean return	45.19	46.46	47.86	48.26	48.09
standard error	13.35	12.83	12.41	12.83	11.06
root mean squared error	2.12	2.21	2.13	2.29	2.42

Note: All measures are in cents per dozen. The measures are calculated as described in table 1. The hedging positions which produced these results are those whose averages were reported in the upper half of table 2.

Table 4. Performance Measures of the Hedging Schemes as the Subjective Weighting of Risk Approaches Zero

	Horizon of Hedge				
	1	2	3	4	5
Using regression forecast					
with $\lambda = -0.1$					
mean return	44.89	46.10	47.51	47.84	47.78
standard error	13.70	12.87	12.59	13.01	11.37
root mean squared error	2.64	2.26	2.23	2.46	2.68
with $\lambda = -0.01$					
mean return	44.73	46.00	47.39	47.74	47.58
standard error	13.80	13.09	12.80	13.26	11.60
root mean squared error	4.71	2.58	2.54	2.75	3.48
with $\lambda = -0.001$					
mean return	43.12	45.08	46.15	46.65	45.55
standard error	17.68	16.47	15.94	16.75	17.19
root mean squared error	31.68	11.26	10.48	10.27	17.28
Using point forecast					
with $\lambda = -0.1$					
mean return	44.93	46.10	47.53	47.95	47.96
standard error	13.64	12.74	12.47	12.91	11.20
root mean squared error	1.96	2.04	2.18	2.36	2.47
with $\lambda = -0.01$					
mean return	44.90	46.23	47.53	47.89	47.87
standard error	13.60	12.96	12.57	12.98	11.25
root mean squared error	2.34	2.15	2.14	2.47	2.53
with $\lambda = -0.001$					
mean return	44.62	47.46	47.47	47.29	47.00
standard error	14.96	15.75	14.10	14.44	12.55
root mean squared error	9.67	5.45	4.83	6.67	6.36

Note: All measures are in cents per dozen. The measures are calculated as described in table 1. The hedging positions which produced these results are those whose averages were reported in the lower half of table 2.

presented by hedging horizon; they are the results of having placed the hedge at various periods before production would actually be ready. Surprisingly, a total hedging scheme compares very favorably with the optimal routines. The squared error loss is often the smallest as compared to the hedges using the forecasts. This result is not inconsistent. The optimal hedges are only optimal from the *ex ante* view. *Ex post,* there clearly were strategies which would have reduced the squared error loss more. There may well be other strategies with this same *ex post* performance. The standard errors of the returns from the total hedging scheme are of a similar magnitude to those obtained for an unhedged routine.

Previous approaches to the analysis of producer hedging would have used essentially those errors as a measure of risk. They suggest that there is little to be gained in stabilizing producer income from a hedging routine. Futures prices are as variable as the subsequent cash prices, and hence the variation in returns would remain unchanged. Reformulating the portfolio problem focused concern only on that portion of the variation in returns which was not predictable. The optimal hedge reduced this variation measurably. Further, the total hedging scheme appeared to be a useful alternative. Costs of hedging have been ignored; the total hedge would lose some of its advantage if they were included. It is, however, costless to implement in the sense of requiring no forecasts or forecast evaluations.

The remaining results, table 4, summarize the performance of the hedging schemes as the expected futures return receives increasing weight. Were the forecasts accurate enough to increase average returns at some cost in acceptable risk levels? The data here clearly show that this is not the case. As the weight assigned to risk decreased, the average returns revealed no tendency to increase. In fact, they tended to decrease. And, of course, the mean squared errors increased. Speculation using these forecasts would probably have proved unprofitable.

Conclusions

Simplifications were numerous in the preceding application of the portfolio approach. The analysis was formulated using returns; costs of production as well as those of futures trading were ignored. Evaluation of the schemes did not attempt to include variation in output levels. Hedgers were not allowed to alter a futures position as the delivery month neared. Other forecasts, either of the same price or of price in a different location, could have been considered. Similarly, better forecasts of basis expected in delivery months could have been devised and examined; however, none of these modifications would substantially alter the basic conclusions.

Futures markets can be a useful tool for the producer attempting to control income variability. Optimal hedging strategies, derived from a portfolio approach, reduced markedly the producer's exposure to unpredictable price variation. Hedging all output over the production period appeared to be a reasonable method of stabilizing revenues which did not depend on interpreting a price forecast. These results depend only on the recognition that some variation in prices and output is desirable. It is the unpredictable portion of price variation which should be of concern.

More work needs to be done with this approach. The static nature of the present analysis should be altered, allowing the producer to revise his hedging position as successive forecasts become available. The model should be extended to include possible uncertainty about actual production. Perhaps most important, however, is the need to evaluate this basic approach using other commodities. Evidence has been presented elsewhere that the new crop future for Maine potatoes (the November future) provides a forward price which is virtually constant from year to year (Tomek and Gray). With an essentially stable forward price at planting time, producers could stabilize their incomes in the standard error sense through a hedging routine. How would the approach used here compare?; that is, how useful would such a future be in reducing only the unpredictable variation in price? Analysis of that situation would delimit most interestingly the measures of usefulness of a futures market to producers interested in more stable incomes.

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An Analysis of Alternative Grain Distribution Systems

George W. Ladd and Dennis R. Lifferth

A transshipment plant location model is used to determine the number, size, and location of new subterminals, expansions in storage capacity of existing country elevators, the rail network, and the monthly flows of grain from origins to elevators to destinations to maximize joint net revenue of grain producers within a 6½-county region. A grain transportation system having fewer rail lines would increase joint net revenue. Country elevators incapable of loading multiple-car trains would be used as storage facilities and transship much of their grain to market through subterminals. Total net revenue varied by 1% or 2% over a wide range of rail abandonment plans.

Key words: transshipment plant location, grain transportation, rail abandonment, physical distribution.

Technological and economic changes are disrupting the grain distribution system. Railroads are introducing multiple-car shipping rates and proposing the abandonment of significant amounts of track. "Big John," covered hopper cars capable of hauling 3,200 bushels of grain are replacing 2,000-bushel capacity boxcars. Multiple-car shipping rates and "Big John" hopper cars complicate the problems of some elevators. Many rail lines require upgrading if they are to sustain hopper cars and multiple-car trains. Many elevators lack adequate rail siding to load twenty or more hopper cars and, therefore, cannot take advantage of multiple-car rates. Fuel shortages are increasing grain-handling and distribution costs. Increases in grain production place added pressures on storage and transportation facilities. Increasing volumes of grain are being shipped to elevators during harvest time, and larger volumes of grain are moving to more distant markets.

To provide an efficient grain distribution system, major adjustments in the grain-marketing system are required. Many of the problems of coordinating such adjustments fall beyond the scope of present regulatory policies; they are also beyond the scope of the pricing system because they require economic agents to know today what actions other agents will take in the future.

The various stages of grain production, handling, and transportation are highly interdependent. Adjustments in one stage should complement the other stages in the marketing channel. In attempts to decide which rail lines should be abandoned, potential elevator sites should be considered. Plans to expand or relocate grain-handling facilities must take into consideration the plans of the railroads.

This paper examines alternative rail-based grain distribution system within a 6½-county region surrounding Fort Dodge, Iowa. The problem might be described as a two-commodity, multiperiod, two-stage hierarchical transshipment problem with variable numbers, sizes, and locations of transshipment plants and variable rail networks to maximize incomes of grain producers. It is multiperiod because monthly flows of grain during the crop year are to be determined. It is a transshipment problem because grain moves from origins to elevators to destinations, and hierarchical and two-stage because grain may move from an origin to a country elevator or subterminal elevator. Grain may move from a country elevator to a subterminal or a final destination but not to another country elevator nor to an origin. Grain may move from a subterminal to a final destination but not to an origin, a country elevator, or another

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subterminal. Numbers, sizes, and locations of subterminals are to be determined, as are expansions in storage capacity of existing country elevators. Rail network is variable because different rail line networks are considered. The objective of the study is to maximize the income received by corn and soybean producers from their commercial sales of these two crops.

Assumptions of Analysis and Exogenous Variables

This analysis is based on the following assumptions. Two grains, corn and soybeans, are shipped from each of 416 origins within the region. Each origin covers a 9-square-mile area. The monthly shipment of each grain from each origin is known. Grain from each origin can be shipped to a country elevator or a subterminal elevator. Country elevators store and ship grain to subterminals and/or final destinations. Subterminals store and ship grain to final destinations. "Final destinations" are either export markets or domestic processing markets.

Country elevators ship grain by truck to a subterminal or by truck, rail, or rail barge to a final destination. Subterminals ship grain by multiple-car rail shipments to final destinations. Country elevators cannot take advantage of twenty-five-car or fifty-car rail rates because they have inadequate load-out capacity or they are located on inadequate rail lines.

Grain received at an elevator may be transshipped immediately or stored for any number of months up to the end of September, the last month of the marketing year.[1] The length of time that grain is stored depends on grain prices at final destinations, transportation costs, storage costs, and elevator capacity. Monthly demand prices are assumed known and vary by commodity and over time for each destination. Per-unit transportation costs vary over time and by commodity.

Economies of scale exist in rail transportation. Total transportation cost includes the minimum annual cost of establishing and maintaining a given rail line option, based on the costs of upgrading, maintaining, and/or abandoning branch rail lines existing in 1971, and the marginal costs of shipping grain by the least costly mode or combination of modes.[2] All costs of upgrading and maintaining branch lines are borne by the grain industry. Maintenance costs for major trunk lines are borne by the railroad industry. Highway costs are included in the marginal cost of shipping grain by truck.

The time horizon over which alternative rail-based grain distribution systems are evaluated extends from 1971 to 1980. Parameters, whose values are taken as given, include the locations of origins and final destinations, and grain distribution facilities existing in 1971, including the locations and capacities of elevators, rail lines, and the highway network.[3] Potential sites for subterminals and alternative rail line systems were developed from consultations with railroad officials, rail users and community planning agencies. The existing country elevators are to continue in use and some may be expanded into subterminals. Perhaps some new subterminals are to be constructed. And some existing rail lines may be abandoned and others upgraded. The constellation of elevators and rail lines that will exist at the end of 1980 depends upon the number, size, and location of facilities existing in 1971.

Elevator construction and/or expansion costs vary by location because they depend upon the size of the existing facility at each location. Total cost of operating a country elevator depends upon the volumes of corn and soybeans handled by the elevator and the 1971 capacity of the elevator. If the volume handled is less than the 1971 capacity, total cost is simply (*a*) marginal cost of storage times volume stored plus (*b*) marginal cost of receiving times volume received plus (*c*) marginal cost of loading-out times volume loaded out. Marginal cost of storage depends upon the commodity and the length of time in storage. Marginal cost of receiving includes drying costs and, therefore, varies by commodity and month. Marginal costs of loading out depend upon method of transportation. If the total quantity stored exceeds 1971 storage capacity, total cost includes (*a*), (*b*), (*c*), (*d*) marginal cost of expanding storage capacity times required expansion in storage capacity, and (*e*) minimum annual average cost of expanding storage capacity of an existing elevator.

[1] Failure to impose this restriction would have lead us into a grain hedging and speculation study.

[2] All total cost functions are linear so marginal cost equals average variable cost. See appendix.

[3] Locations, receiving, storing, and load-out capacities of all elevators in the area were inventoried before beginning the analysis.

The fixed cost of expanding a plant or constructing new receiving, drying, and load-out facilities at a plant is independent of volume but varies by elevator type. Country elevators that expand to a subterminal status must expand receiving, drying, and load-out facilities to meet the minimum capacity requirements of a subterminal. Any new subterminal must meet these same capacity requirements. Total annual construction or expansion costs of storage facilities consist of a fixed cost that reflects the minimum annual cost of constructing storage facilities and a marginal expansion cost that reflects the additional costs of expansion to store one more bushel of grain.

To avoid solutions in which substantial numbers of existing elevators are underutilized at the same time that new facilities are being constructed, a capacity expansion constraint is imposed. No elevator can expand storage capacity as long as unused storage capacity exists at any other elevator.[4]

Model

The 1971 number, location, and storage capacities of country elevators, and the 1971 rail line network are fixed, but the 1980 storage capacities of country elevators and the 1980 rail line network are to be determined. Other variables whose values are endogenously determined for 1980 are number, location, and storage capacity of subterminals, and the spatial and temporal movements of each grain from origins to final destinations. Such flows include the monthly volumes of each grain received at country elevators from each origin, the monthly volumes of each grain shipped from country elevators to each subterminal and final destination, the monthly volumes of each grain received at subterminals from each origin and country elevator, the monthly volumes of each grain shipped from subterminals to each final destination, and the monthly volumes of each grain in storage at each country elevator and subterminal.

The model determines values of the endogenous variables to heuristically maximize the joint net revenue of corn and soybean producers in 1980.[5] Net revenue is the income received at final destinations minus storage, transportation, receiving, loading-out and drying costs. For this problem, net revenue maximization is superior to cost minimization because prices vary by destination, and prices are used to determine seasonal storage patterns.

Various material balance conditions are imposed. Constraints insure that the total supply of each grain received at any one location in month t equals the total supply shipped to that location from all sources in month t. The amount of a commodity stored at an elevator at the beginning of month t equals cumulative receipts minus cumulative shipments of the commodity up to month t. Other restrictions insure that total annual receipts of a commodity at an elevator equal total annual outshipments of the commodity.

Method of Solution

Stollsteimer developed a model to determine the optimal number, size, and location of plants (or warehouses) when transport costs from origins to plants or transport costs from plants to destinations (but not both) are relevant. The method of solution we use extends the Stollsteimer model to determine the heuristic optimal number, size, and location of plants when (*a*) transport costs from origins to plants and transport costs from plants to destinations are relevant, (*b*) multiple transshipment over time and space occur, (*c*) facilities exist at the beginning of the planning horizon, (*d*) a capacity expansion constraint is imposed, and (*e*) economies of scale in rail transportation exist.

The method of solution is divided into two parts. Part I is run once for each locational pattern of country elevators, subterminals, and rail lines. All country elevators existing in 1971 are included in each locational pattern analyzed. Each run of part I determines the spatial and temporal flows of grain from origins to final destinations that provide the maximum revenue net of variable transportation and grain-handling costs for one locational pattern of elevators and rail lines.

[4] As it turned out, this constraint was redundant. Because use of existing facilities is much cheaper than use of new facilities, routine application of objective function criteria automatically resulted in solutions that satisfy this constraint.

[5] We used a heuristic solution procedure. Heuristic procedures for solving plant location problems have been published by Candler, Snyder, and Faught; Chern and Polopolus; King and Logan; and Warrack and Fletcher. No heuristic procedure can be proven to provide a global optimum solution to a maximizing problem. Likewise, our procedure cannot be proven to provide a maximizing solution to our problem. The term heuristic maximum or heuristic optimum is used in the text to mean the value estimated to be maximum or optimum by a heuristic procedure.

Revenue net of variable costs equals total expenditures for grain FOB final markets minus variable costs associated with storing and transporting grain through facilities in λ_{mnr}; λ_{mnr} denotes the mth set of n subterminals and rth rail network. Part II determines the one locational pattern of rail lines and elevators for which joint revenue net of all costs (variable and fixed) of grain transportation and handling is heuristically maximized.

Part I contains two subroutines—ORA(1, t) | λ_{mnr} and ORA(2, t) | λ_{mnr}—to determine the heuristic optimal distribution of grain for each rail line network and each set of elevators. ORA(1, t) | λ_{mnr} denotes the first optimal routing algorithm given λ_{mnr} and month t. ORA(2, t) | λ_{mnr} denotes the second optimal routing algorithm given λ_{mnr} and month t. For brevity these algorithms will be referred to as ORA(1, t) and ORA(2, t). Both subroutines are described in greater detail in the appendix.

Before initiation of ORA(1, t), the marginal cost of storing grain is specified for each elevator. It is set equal to either the marginal costs for storage in existing facilities or the marginal costs of storage in existing facilities plus the marginal costs of expanding storage facilities.

For each λ_{mnr}, ORA(1, t) determines the flows of grain over time and space to maximize revenue net of variable costs. ORA(1, t) is repeated for each λ_{mnr} for each month. The solution of ORA(1, t) is optimal if the data (marginal storage cost functions) are consistent with the solution (the volumes stored). For example, if the marginal storage cost function for a country elevator was set equal to marginal cost of using existing facilities but the solution called for storing more than existing facilities could hold, data and solution are inconsistent. When the storage cost data of ORA(1, t) are inconsistent with the solution of ORA(1, t), ORA(2, t) is used to determine the optimal flows of grain for each λ_{mnr}.

The second routing algorithm assumes that marginal storage costs are dependent on the volume of grain stored. It also takes into account the expansion constraint that no elevator can expand storage capacity as long as unused storage capacity exists at any other elevator. It assumes constant marginal costs of receiving, loading-out, and transporting grain.

ORA(2, t) uses the solution to ORA(1, t) as a first approximate solution. If the volume stored at an elevator during period t, as determined by ORA(1, t), is greater than the storage capacity of the elevator during period t then three options are available. Grain may be rerouted from storage in that elevator spatially and/or temporally; the storage capacity at that elevator may be expanded; or a combination of rerouting and storage capacity expansion is possible. As long as at least one elevator has unused storage capacity, however, grain must be rerouted to that elevator. Once the capacity expansion restriction has been met and no elevator has unused storage capacity but some have deficit storage capacity, losses in revenue resulting from temporal rerouting of grain to reduce storage requirements must be compared with additional costs of expanding storage capacity. Joint net revenue is maximized over twelve months. Expanding storage capacity in period t may influence the spatial and temporal routing of grain in period $t + 1, t + 2, \ldots, 12$. The additional cost of expanding storage capacity at one location during period t must be compared with the net revenue lost over all time periods from the rerouting of grain if storage capacity is not added.

The objective of part II is to select the number and locational pattern of subterminals, country elevators, and the rail line system for which joint net revenue of producers is heuristically maximized. Joint net revenue is computed for each locational pattern of rail lines and elevators by subtracting the fixed costs required to establish the system from the revenue net of variable costs as determined from part I. Heuristic maximum joint net revenue is found by systematically computing joint net revenue for each combination of rail lines and elevators and selecting that constellation of elevators and rail lines for which joint net revenue is a heuristic maximum.

Comparison with Boissevain Study

Our study has a number of similarities with the Tyrchniewicz and Tosterud study of grain collection and distribution systems in the Boissevain region of Canada. Our study differs from theirs in several ways. Theirs was a one-period analysis whereas we analyzed monthly flows. Their study dealt with one grain (per-bushel costs were the same for all grains) whereas we studied two grains. In their study, all grain was shipped to one final

market; the choice of final markets was part of our analysis. Their study involved one stage of transshipment whereas ours involved two stages. We imposed capacity expansion constraints (to assure full utilization of existing elevators) and used switching rules (to adjust cost coefficients). Costs of maintaining various rail line options were included in our study. We used the same criterion to determine shipments from farm to elevator as we used to determine shipments from elevator to final market. They used one rule to determine shipments from elevator to final market and other rules to determine farm-to-elevator shipments.

Results

A number of solutions were obtained in order to analyze effects of different rail abandonment plans, different rate structures, and different prices. The results are summarized here, and other results are reported in Baumel et al. and in Lifferth.

Three rail line options referred to in the tables are as follows. Option I is to maintain the existing lines at their 1971 capacities. Elevators located on light lines could not ship fully loaded hopper cars. (A light rail line was not capable of carrying fully loaded jumbo covered hopper cars.) These elevators could use boxcars, small covered hoppers, or partly loaded jumbo covered hopper cars to move the grain by rail.

Option II is to maintain 46% of the 702 miles of track in the Fort Dodge area, abandon some light lines, upgrade others, and leave still others at their 1971 capacities. This option eliminates the fixed component of annual maintenance costs of the abandoned lines; the variable component shifts to the remaining lines which would carry the additional traffic.

Option III is to abandon all existing light lines and retain only those major trunk lines that had the capacity to handle loaded hopper cars in 1971. This option would maintain 27% of the rail line in the area and would eliminate the fixed component of the annual maintenance costs of branch lines and provide some revenue from the salvage value of the abandoned lines. The variable component of the maintenance cost would shift to the remaining lines carrying the additional traffic.

In deriving the solutions presented here, the proportion of the estimated 1980 annual volume of each grain shipped each month from each origin is the proportion of the 1971 annual volume of that grain actually marketed by farmers each month in the Fort Dodge area.

In addition to results here, the solution algorithm was used to determine highway maintenance and resurfacing costs attributable to truck shipments of grain. It could be used to determine fuel consumption and pollution emissions. The solutions also specified heuristic optimal spatial and temporal storage and shipping patterns for all grain shipped from each origin.

Table 1 summarizes revenue and cost data for one set of analyses based on 1971 rates. The highest net revenue was obtained from a system of ten subterminals loading fifty-car trains on rail line option III. This system yielded 5.1¢ net revenue per bushel above the traditional single-car system moving the same quantity of grain. The net revenue from this option was only 0.2¢ per bushel greater than the net revenue from option II.

Under option III, the Chicago export market received 34% of the commercial corn and 25% of the commercial soybeans; the Gulf export market received 55% of the commercial corn and 71% of the commercial soybeans. The annual volumes of the ten subterminals ranged from 4.5 to 15.7 million bushels of grain. Country elevators handled 48% of the grain marketed. They shipped 9% directly to final market by rail and trucked 39% to subterminals, who in turn transshipped the grain to final markets in fifty-car units. Subterminals received 52% of the commercial grain directly from farmers and shipped the grain to final markets in fifty-car units. Table 2 summarizes investment costs required to handle 1980 commercial shipments under the traditional single-car system and rail line option II.

Domestic prices for corn and soybeans were higher relative to export prices in 1970–71 than in 1969–70. This tended to increase shipments to domestic markets and reduce shipments to ports of export. In the analysis reported in tables 1 and 2, subterminals have advantages over country elevators on shipments to ports but not on shipments to domestic markets, because multiple-car rates apply only to shipments to ports and (higher) single-car rates apply on shipments to domestic markets. What is the effect on the heuristic optimum number of subterminals of higher domestic prices? Table 3 summarizes the results of analysis that used the same cost and

Table 1. Heuristic Optimal Solutions for Grain Distribution Systems Based on Three Rail Line Options and 1969–70 Grain Prices

Item	Rail Line Options: Option I: Maintain 1971 Rail System	Option II: Keep 46% of 1971 Rail System	Option III: Keep 27% of 1971 Rail System
Total revenue minus all variable transportation, storage, and handling costs	$182,178,000	$182,846,000	$181,990,000
Less annual subterminal investment costs	$ 764,000	$ 1,000,000	$ 775,000
Less annual rail line maintenance and upgrading costs	$ 2,794,000	$ 1,807,000	$ 994,000
Total joint net revenue	$178,620,000	$180,039,000	$180,221,000
Number of subterminals in the 6½-county area	10	13	10
Increase in total joint net revenue over 1971 system[a]	$ 4,411,000	$ 5,843,000	$ 6,012,000
Increase in net revenue over 1971 system from			
(*a*) rail rate reductions less trucking and handling costs	$ 4,411,000	$ 4,843,000	$ 4,212,000
(*b*) reduction in rail line maintenance costs	0	$ 987,000	$ 1,800,000
Increase in total joint net revenue over 1971 system in ¢ per bushel	3.7	4.9	5.1

Source: Baumel et al. (p. 68).
Note: Single-car rates applied to shipments to domestic markets; multicar rail rates applied to shipments to ports of export.
[a] 1971 system: No multiple-car rail rates, only single-car rail rates.

rate data as table 1 but used 1970–71 corn and soybean prices. The amount of grain shipped to ports declined about one-fifth with the higher domestic prices, and the optimum number of subterminals declined. Rail line option III still provided the heuristic maximum net revenue. Net revenue was also determined for a rail line option in which all light rail lines were upgraded to handle fully loaded covered hopper cars. The net revenue for this option was 1.6¢ per bushel lower than the net revenue for option III in table 3.

The multiple-car rate used in obtaining the previous results was the 50-car rate. Another set of solutions was obtained using an estimated 115-car, unit-train rate in place of the 50-car rate. The 115-car rate is based on a guaranteed annual volume of 517,000 tons per

Table 2. Estimated Investment Costs to Implement Two Grain Distribution Systems

Type of Investment	Traditional Single-Car System	Single-car, 3- to 10-car, and 50-car System on Rail Line, Option II
Subterminals (additional)	$ 0	$ 6,038,504
Storage (additional)	15,115,576	15,115,576
810-bushel trucks (additional)	0	510,816
450-bushel trucks (total)[a]	93,940	213,220
300-bushel trucks (total)[a]	1,034,025	1,117,800
450-bushel wagons (total)[a]	2,211,984	2,997,888
Rail cars (total)[b]	46,578,500	34,077,000
Rail lines (additional)	10,388,172	5,841,080
Total	$75,422,197	$65,911,884

Source: Baumel et al. (p. 104).
[a] Total investment costs are given for trucks and wagons based on estimated needs. Additional costs could not be estimated because of lack of data on existing equipment.
[b] Total investment costs are given for rail cars based on estimated needs. The additional investment costs could not be computed because of the lack of data on the percentage of car days used in the 6½ counties.

Table 3. Heuristic Solutions for Grain Distribution Systems Based on Three Rail Line Options and 1970–71 Grain Prices

	Rail Line Options		
	Option I: Maintain 1971 Rail System	Option II: Keep 46% of 1971 System	Option III: Keep 27% of 1971 System
Total revenue minus all variable transportation, storage, and handling costs	$215,520,000	$215,104,000	$214,598,000
Less annual subterminal investment costs	$ 536,000	$ 592,000	$ 530,000
Less annual rail line maintenance and upgrading costs	$ 2,794,000	$ 1,807,000	$ 994,000
Total joint net revenue	$212,190,000	$212,705,000	$213,074,000
Number of subterminals in the 6½-county area	7	8	7

Source: Baumel et al. (p. 83).
Note: Single-car rates applied to shipments to domestic markets; multicar rail rates applied to shipments to ports of export.

year and would require the train to run continuously throughout the year. Use of the 115-car rate increased the heuristic total joint net revenue by some $2.5 million for rail line option II and by some $3.2 million for option III over the joint net revenues in table 1. Use of the 115-car rate also reduced the heuristic optimal number of subterminals and hence reduced the additional storage investment required from the $15.1 million in table 2 to $10.2 million. And it reduced the total need for investment in rail cars from the $34.1 million reported in table 2 down to $15.9 million.

Because rail rates may not reflect cost differences and barge rates fluctuate with changing demand for barge transportation, another set of solutions was obtained using rail and barge costs rather than rail and barge rates.

Some general findings of the study were as follows. Total net revenue varied by 1% to 2% (0.8¢ to 1.6¢ per bushel) over a wide range of abandonment plans. Country elevators incapable of loading multiple-car trains were used as storage facilities and transshiped much of their grain to market through subterminals. Grain producers shipped to country elevators and subterminals during harvest months and shipped to subterminals during other months.

The study suggests that a grain transportation system having fewer light rail lines would increase joint net revenue of grain producers. The only commodities covered in this study were corn and soybeans, however. It is possible that if other commodities, e.g., fertilizer, had been included, the heuristic optimum rail line option would have included more of the 1971 rail line system.

Some Implications

Changes in the present rail line network, adoption of multiple-car (and unit-train) rates, and replacement of boxcars by hopper cars create opportunities and problems for grain producers and elevators. Given the changes to be made by the railroads, the cooperative and proprietary elevators are engaged in a nonzero sum game. Neither the total gains made by all elevators nor the gain to each elevator is independent of the actions of each elevator. Some actions that benefit one elevator can harm others; some actions that benefit him equally can also benefit others. As Baumel et al. observed, "Unwillingness of both country elevator and subterminal operators to work together could delay implementation of the selected alternatives. Country elevator operators fear that the subterminal system will place them in an inferior bargaining position through reduced marketing alternatives. Subterminal operators have displayed some evidence that they may try to force country elevators out of business through bidding procedures. Thus, a cooperative effort by both country elevator and subterminal operators is needed to enable them to work together to gain the benefits" (p. 125).

In addition, the changes that will be made by the railroads and the benefits they realize from these changes will depend upon the way in which grain producers and elevators (and other rail users) respond to these changes. This introduces another set of players and another source of conflict and uncertainty into the nonzero sum game. Again, as Baumel et

al. write, "The system which actually develops will depend on what rail abandonment actually occurs and the extent to which the grain industry, carriers and farmers are willing to work together. . . . these people must weigh the benefits of the model system against the problems of individual adjustments, . . . continuing transportation problems and the risk of rail abandonment and over-investing in facilities if each unit decides to go its own way in an unplanned system" (p. 123).

The method and results of this study lead to two suggestions for modifying existing policies on rail abandonment regulation. Strengthen the criteria and information base for decision making by quantitatively estimating the impact of rail abandonment through systematic analysis, taking into account both inter- and intramodal effects. Enlarge the scope of activities subject to rail abandonment regulation by including inter- and intramodal rate flexibility designed to assist railroads forced to operate weak lines for "public convenience and necessity." Implicit in both of these is consideration of side effects or externalities. In this study, a number of externalities, e.g., highway costs, rail maintenance and upgrading costs, and abandonment of existing elevators, were internalized by the method of analysis.

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Appendix

Small Versions of ORA(1, t) and ORA(2, t)

The problems presented here are simpler than the problems solved by ORA(1, t) and ORA(2, t), and the procedures are revised versions of the procedures actually used. For complete discussions of ORA(1, t) and ORA(2, t), see Lifferth. For complete discussions of the procedures in this appendix, see Ladd.

Define the symbols:

S_i, L_j, M_h = origin or source i, plant location j, final market h; $i = 1, 2, \ldots, I$; $j = 1, 2, \ldots, J$; $h = 1, 2, \ldots, H$;

$X(i\cdot\cdot)$ = quantity of raw material shipped from S_i;

$X(ijh)$ = quantity shipped from S_i through L_j to M_h in raw material equivalents;

$X(\cdot j\cdot)$ $= \sum_{i=1}^{I}\sum_{h=1}^{H} X(ijh)$ = quantity of product received and processed at L_j and shipped to final markets;

$X(\cdot\cdot h)$ $= \sum_{i=1}^{I}\sum_{j=1}^{J} X(ijh)$ = total quantity of product, in raw material equivalents, shipped to M_h;

X $= \sum_{i=1}^{I} X(i\cdot\cdot) = \sum_{j=1}^{J} X(\cdot j\cdot) = \sum_{h=1}^{H} X(\cdot\cdot h)$;

$P(\cdot\cdot h)$ = price of final product at M_h, in raw material equivalents;

$C(ij\cdot)$ = per-unit cost for transporting raw material from S_i to L_j;

$C(\cdot jh)$ = per-unit cost, in raw material equivalents, for transporting final product from L_j to M_h;

$C(ijh)$ $= C(ij\cdot) + C(\cdot jh)$;

TPC_j $= \alpha(j) + \beta(j)X(\cdot j\cdot)$ = total processing cost for plant at L_j; $\beta(j)$ is marginal processing cost at L_j;

and

$\lambda\ (km)$ = kth set of m plant sites, $m \leq J$; $k = 1, 2, \ldots, J!/m!(J - m)!$

$X(i\cdot\cdot)$, X, $P(\cdot\cdot h)$, $C(ij\cdot)$, $C(\cdot jh)$, $C(ijh)$, $\alpha(j)$, and $\beta(j)$ are known constants; $X(ijh)$, $X(\cdot j\cdot)$, and $X(\cdot\cdot h)$ are variables.

Simple Version of ORA(1, t)

The problem to be solved is: Determine m, $\lambda(km)$, and $X(ijh)$ to maximize

$$\text{(A.1)}\quad \sum_i \sum_{j\epsilon\lambda(km)} \sum_h [P(\cdot\cdot h) - C(ijh) - \beta(j)]X(ijh) - \sum_{j\epsilon\lambda(km)} \alpha(j).$$

This transshipment plant location problem can be converted into a problem that is essentially case II in Stollsteimer's paper and solved by a slight variation of his procedure.

The average revenue net of transport and variable processing cost (ARN) for product shipped from S_i through L_j to M_h is $P(\cdot\cdot h) - C(\cdot jh) - C(ij\cdot) - \beta(j)$. Denote the maximum ARN attainable at S_i for product shipped through L_j as

$$\text{(A.2)}\quad \pi(ijh_{ij}) = \max_h[P(\cdot\cdot h) - C(\cdot jh)] - C(ij\cdot) - \beta(j).$$

This maximum ARN is obtained by shipping from L_j to $M_{h_{ij}}$. And the maximum ARN obtained at $S_u (u \neq i)$ for product shipped to L_j is also obtained by shipping finished product to $M_{h_{ij}}$, that is, $H_{uj} = h_{ij}$ for all i and u for j fixed. We can, therefore, define $h_j = h_{ij} = h_{uj}$ for all S_i and S_u, and write equation (A.2):

$$\text{(A.3)}\quad \pi(ijh_j) = \pi(ijh_{ij})$$

for all S_i. Once j is specified and equation (A.2) is computed for $i = 1$, h_j is uniquely determined. Now specifying L_j provides two bits of information. It identifies a plant site, as before. It identifies the final market M_{h_j} to which all products received and processed at L_j will be shipped for maximum ARN.

The first step in solving the problem is to compute equation (A.2) for $i = 1$ for all combinations of values of j and h. For $u > 1$, compute

$$\text{(A.4)}\quad \pi(ujh_j) = P(\cdot\cdot h_{1j}) - C(\cdot jh_{1j}) - C(uj\cdot) - \beta(j)$$

for all j. These computations provide an $I \times J$ matrix $[\pi(ijh_j)]$ of ARN.

For a given $\lambda(km)$, the maximum ARN attainable at S_i for shipping through some plant in $\lambda(km)$ is

$$\text{(A.5)}\quad \max_{j\epsilon\lambda(km)} \pi(ijh_j).$$

For a given $\lambda(km)$, the maximum attainable net revenue (NR = total revenue minus transport and variable and fixed processing costs) is

$$\text{(A.6)}\quad \overline{NR} \mid \lambda(km) = \sum_i \sum_{j\epsilon\lambda(km)} \sum_h X(i\cdot\cdot)\left[\max_{j\epsilon\lambda(km)} \pi(ijh_j)\right] - \sum_{j\epsilon\lambda(km)} \alpha(j).$$

The maximum attainable NR from m plants is

$$\text{(A.7)}\quad \overline{NR} \mid m = \max_k \overline{NR} \mid \lambda(km).$$

The set of plant sites and routings that maximizes equation (A.1) is the set that provides

$$\text{(A.8)}\quad \overline{NR} = \max_m \overline{NR} \mid m.$$

In ORA(1, t) each geographic point for a final market represented twelve different final markets, one for each month. ORA(1, t) dealt with two commodities and contained two levels of transshipment plants, country elevators and subterminals.

Simple Version of ORA(2, t)

The preceding problem ignores existing plants. It deals only with number, size, and location of new plants. In ORA(2, t) some plants are in existence initially, but their total processing capacity is insufficient to handle all available raw material. Additional processing capacity is needed. It can be obtained by increasing the size of (some or all) existing plants or by building new plants or by doing both.

Divide each $\lambda(km)$ into two subsets:

$\lambda(km) = \{\lambda(km_1), \lambda(km_2)\}$,
$\lambda(km_1)$ = set of m_1 sites in $\lambda(km)$ where plants now exist,
$\lambda(km_2)$ = set of m_2 sites in $\lambda(km)$ where plants do not now exist but where new plants may be built, and
$m = m_1 + m_2$.

Also define:

$Z(\cdot j\cdot)$ = initial capacity of existing plant at $L_j\epsilon\lambda(km_1)$.

Define:

$$D(j) = 1 \text{ if } X(\cdot j\cdot) > Z(\cdot j\cdot),$$
$$D(j) = 0 \text{ if } X(\cdot j\cdot) \leq Z(\cdot j\cdot),$$

and

$$\beta_2 > \beta_1.$$

The TPC function for a plant at $L_j\epsilon\lambda(km_1)$ is

$$\text{(A.9)}\quad TPC1_j = \alpha_1 D(j) + \beta_1 X(\cdot j\cdot) - \beta_1 D(j)[X(\cdot j\cdot) - Z(\cdot j\cdot)] + \beta_2 D(j)[X(\cdot j\cdot) - Z(\cdot j\cdot)].$$

If this plant operates at or below its initial capacity, $TPC1_j = \beta_1(X\cdot j\cdot)$. If the plant operates at a level above its initial capacity, $TPC1_j = \alpha_1 + (\beta_1 - \beta_2)Z(\cdot j\cdot) + \beta_2 X(\cdot j\cdot) = \alpha_1 + \beta_1 Z(\cdot j\cdot) + \beta_2[X(\cdot j\cdot) - Z(\cdot j\cdot)]$. The TPC function for a new plant located at L_t is

$$\text{(A.10)}\quad TPC2_t = \alpha_2 + \beta_3 X(\cdot t\cdot)$$

and

$$\beta_3 > \beta_1;\ \alpha_2 > \alpha_1,\ \beta_3 \gtreqless \beta_2.$$

The problem to be solved can be written: Determine m_1, m_2, $\lambda(km)$, $X(ijh)$, and $D(j)$ to maximize

$$\begin{aligned}(\text{A.11})\quad \sum_{i}\sum_{j\in\lambda(km_1)}\sum_{h} \{&P(\cdot\cdot h) - C(ijh) \\ &- [\beta_1 - \beta_1 D(j) + \beta_2 D(j)]\}\, X(ijh) \\ &- (\beta_1 - \beta_2) \sum_{j\in\lambda(km_1)} D(j) Z(\cdot j \cdot) \\ &- \alpha_1 \sum_{j\in\lambda(km_1)} D(j) \\ &+ \sum_{i}\sum_{j\in\lambda(km_2)}\sum_{h} [P(\cdot\cdot h) \\ &- C(ijh) - \beta_3] X(ijh) - \alpha_2 m_2.\end{aligned}$$

This objective function is nonlinear because it contains the product terms $D(j)\, X(ijh)$, each of which is a function of the other. The ORA(1, t) procedure cannot be used because that procedure requires knowing $TPC1_j$ to determine $X(ijh)$, but here $TPC1_j$ is not known until $X(ijh)$, and therefore $D(j)$, is known. This nonlinear combinatorial problem can be solved by a five-stage heuristic procedure. Space limitations make it impossible to present complete details here. For complete details, see Ladd.

Stage 1. In this stage, set $D(j) = 1$ for all existing plants and determine $\pi(ijh_j)$ and $\alpha(j)$ accordingly for existing plants. (For new plants $\alpha(j) = \alpha_2$ and $\beta(j) = \beta_3$.) Now equation (A.11) is exactly the same as equation (A.1). Use ORA(1, t) to solve this problem. After applying ORA(1, t) to every λ (km), divide the λ (km) into three sets:

$L(N)$ = set of λ (km) containing only sites where no plants now exist;

$L(E1)$ = set of λ (km) containing sites where plants now exist; for every λ (km) in this set, $Z(\cdot j \cdot) < X(\cdot j \cdot)$ for every existing plant in λ (km);

$L(E2)$ = set of λ (km) containing sites where plants now exist; for every λ (km) in this set $Z(\cdot j \cdot) \geqslant X(\cdot j \cdot)$ for some existing plants in λ (km).

$L(E1)$ and $L(E2)$ contain sites where plants now exist; they may also contain sites where no plants now exist. Every $\lambda\,(km)$ is a set of plant sites; $L(N)$, $LE(1)$, and $LE(2)$ are sets of sets of plant sites.

For those λ (km) that are in $L(N)$, no further computations are needed to determine optimum routings and $\overline{NR} \mid \lambda$ (km). For those λ (km) that are in $L(E1)$, go to stage 4. For those λ $(km) \in L(E2)$, go to stage 2, then stage 3, then stage 4.

Stage 2. Because $X(\cdot j \cdot) \leqslant Z(\cdot j \cdot)$ for some existing plants, the solution to ORA(1, t) is not consistent with the original specification that $D(j) = 1$; ($D(j) = 1$ implies $X(\cdot j \cdot) > Z(\cdot j \cdot)$. Recompute $TPC1_j$ for each existing plant operating at or below capacity, recompute the affected values of $\pi(ijh_j)$, and recompute NR. Define:

λ (km_1-) = set of $L_j \epsilon \lambda$ (km_1) whose receipts in ORA(1, t) solution equal or fall short of their initial capacities, and

λ (km_1+) = set of $L_j \epsilon \lambda$ (km_1) whose receipts in the ORA(1, t) solution exceed their initial capacities.

Stage 3. Because $\beta_3 > \beta_1$ and $\beta_2 > \beta_1$, for a given λ $(km) \epsilon L(E2)$, it is always possible to reduce TPC by reducing shipments to $L_j \epsilon \lambda$ (km_2) and $L_j \epsilon \lambda$ (km_1+) and increasing shipments to $L_j \epsilon \lambda$ (km_1-), provided receipts at $L_j \epsilon \lambda$ (km_1-) do not rise above $Z(\cdot j \cdot)$. This rerouting will affect total transport cost and may affect gross revenue. Stage 3 determines the reroutings that will increase NR.

The heart of this stage involves construction of a matrix $[\Delta NR\ (dgv) \mid \lambda\ (km)]$ whose typical element

$\Delta NR\ (dgv) \mid \lambda\ (km)$ = maximum increase (or minimum decrease) in net revenue if S_d's raw material, originally shipped to L_g, is rerouted to L_v. $L_g \epsilon \lambda$ (km_1+) or $L_g \epsilon \lambda$ (km_2). $L_v \epsilon \lambda$ (km_1-).

Three restrictions are incorporated into the construction of $[\Delta NR\,(dgv) \mid \lambda(km)]$. Volume at $L_g \epsilon \lambda(km_1+)$ cannot fall below initial capacity of that plant. Volume at $L_g \epsilon \lambda$ (km_2) cannot fall below zero. Volume at $L_v \epsilon \lambda (km_1-)$ cannot rise above initial capacity of the plant at L_v.

If all elements of the matrix are negative, no rerouting is done. If it has positive elements, the largest one determines how much should be rerouted and which plants gain and lose volume. If the matrix has positive elements, incorporating the three restrictions involves constructing a sequence of matrices. After one is constructed and material from one S_d is rerouted away from one L_g to one L_v, a second matrix is constructed, a second rerouting is selected, and so on until no more reroutings that satisfy the restrictions serve to increase NR. After all profitable reroutings have been made, TPC functions are recomputed for $L_j \epsilon \lambda\,(km_1+)$ whose volumes have been reduced to their initial capacities, and affected $\pi\ (ijh_j)$ and NR must be recomputed.

This series of computations is carried out for each set of m sites, each set of $m \pm 1$ sites, and so on.

Stage 4. If the solution in stage 3 calls for two or more existing plants to expand their capacities, TPC can be reduced by rerouting raw material to reduce the number of existing plants required to expand. Stage 4 computations determine how to reroute shipments to increase NR by reducing the number of existing plants required to expand. At the heart of stage 4 is computation of

$\Delta NR\ (p) \mid \lambda\ (km)$ = maximum increase generated in NR if enough material is rerouted away from $L_p \epsilon \lambda$ (km_1+) to bring $X(\cdot p \cdot)$ down to $Z(\cdot p \cdot)$.

Computation of $\Delta NR\ (p) \mid \lambda\ (km)$ also determines those sources whose raw material should be rerouted away from Lp and determines the plants the material should be rerouted to.

If all values of $\Delta NR\ (p) \mid \lambda\ (km)$ are negative, no profitable rerouting is possible. If some $\Delta NR\ (p) \mid \lambda\ (km) > 0$, profitable rerouting is carried out. Then $\Delta NR\ (p) \mid \lambda\ (km)$ is computed for another $L_p \epsilon \lambda$ (km_1+) and rerouting is carried out if profitable. This process continues until no more opportunity exists for profitable rerouting; TPC functions

are adjusted for $L_p \epsilon \lambda$ (km_1+) whose volumes have been reduced to their initial capacities, affected values of $\pi(ljh_j)$ are adjusted, and *NR* is computed.

Stage 5. In stage 5, results from previous stages are compared to determine the heuristic optimum number, size and location of plants, and pattern of shipments. These computations correspond to the computations carried out in part II of the solution algorithm described in the text.

A Spatiotemporal Quality Competition Model of the Australian Sugarcane Processing Industry

G. J. Ryland and J. W. B. Guise

An activity analysis model is developed to determine the optimum period of production at a chain of sugarcane processing plants and the optimal regional transport network flows of cane and raw sugar. Explicit treatment is given to discrete variations in input quality which affect revenue at each plant location in each time period. Optimal solutions to three market configurations open to a multifacility monopolist—spatiotemporal quality competition, spatial quality competition, and pure competition—are obtained. Results suggest that, for given output, industry net revenues can be increased when explicit consideration is given to input quality variations relative to industry net revenues associated with treating inputs as homogeneous.

Key words: sugar processing, spatial equilibrium, input quality.

The most general of interregional competition models should provide for simultaneous adjustments when price, space, time, and quality change. The development of spatial equilibrium models of either the activity analysis or standard equilibrium type generally proceed on the assumption that the price-space parameters involve only a single industry producing a single homogeneous product. Studies to determine an optimum quality mix of a single product for a firm or an industry producing a spectrum of qualities as a result of biological factors in the production process have been a neglected area of empirical demand and supply analysis.[1] Matsumoto and French have used the monopolistic framework provided by Waugh to determine the optimal price-quality distribution of brussel sprouts in a spaceless and timeless economic environment. While they recognized that locational and seasonal influences are important, their empirical analysis did not include spatial or temporal variation in quality which is typical of many agricultural products harvested seasonally.

In this paper we abstract from final product demand considerations and consider a regulated industry producing a standard form of final product from raw material inputs which differ in quality over time and among plant locations. The objectives of this paper are to determine the net revenue-maximizing behavior of a cartel-type processing industry producing a fixed quota of standard-grade raw sugar when the raw material input, sugarcane, follows a time-dependent quality cycle over a season and to show the effect on industry revenues if spatial and temporal variation in input quality are not included in the allocation model.

"Quality" Horizon Planning in Sugarcane Processing

The purpose of this section is to outline the production principles relevant for the multifacility sugarcane processor. These principles will be helpful in selecting the optimum period of production (starting and finishing dates) which determine the volume of production at each plant over a season usually less than

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[1] There are two basic approaches to the problem of incorporating quality variations over time of a single product in empirical demand analysis at the aggregate level which depend upon the importance of brand effects. The first approach used by Cowling and Rayner involves the specification of a lagged relationship by which consumers gradually adjust price changes over time to changes in quality over time in the context of analyzing the market share behavior of branded goods. In the absence of brand effects, all adjustments are assumed to occur instantaneously; this approach is used here.

six months duration.[2] Throughout, we impose the following specifications: $\alpha(t)$ = a quality adjuster, representing the percentage of commercial cane sugar (CCS) content in the supplies of sugarcane, which may be expressed as a quadratic function of time of the form $\alpha(t) = \gamma_0 + \gamma_1 t + \gamma_2 t^2$ ($\gamma_0, \gamma_1 > 0, \gamma_2 < 0$), where t is measured in one-week units with a fixed origin; $\beta(t)$ = a quality adjuster following a similar behavioral pattern as $\alpha(t)$ and represents the grower's share of quality in each time period; $K(t)$ = volume of sugarcane processed in each time period following a similar behavioral time trend as $\alpha(t)$; P = fixed price of the quality-adjusted raw material in terms of standardized final product equivalents over the season; and C = total processing cost function specified as a quadratic function of the accumulated volume of throughput, X, of the form, $C = \delta_0 + \delta_1 X + \delta_2 X^2$; $\delta_0\ \delta_1\ \delta_2 > 0$, where $X = \int_a^b K(t)\,dt$ throughout the processing interval $(b - a)$.[3] When the form of $K(t)$ is specified, total processing cost C may be expressed as a function of the processing interval $(b - a)$:

$$C = k(b - a). \tag{1}$$

Using the above relationships, the processor's revenue R over the processing interval $b - a$ can be expressed as

$$\begin{aligned} R &= P[\int_a^b (\alpha(t) - \beta(t))\,K(t)\,dt] \\ &= F(b) - F(a), \end{aligned} \tag{2}$$

from which must be deducted total processing costs C to determine the processor's annual profit π. The sugar miller must determine optimal values of starting and finishing date (b^* and a^*) for processing each season which may be obtained from the parametric profit function as follows:

$$\begin{aligned} \pi &= R - C \\ &= F(b) - F(a) - k(b - a). \end{aligned} \tag{3}$$

Providing the concavity requirements of equation (3) are met, the requirements for optimum length of processing period are

$$\frac{\partial \pi}{\partial b} = F'(b) = k'(b - a), \tag{4}$$

and

$$\frac{\partial \pi}{\partial a} = F'(a) = k'(b - a). \tag{5}$$

Equations (4) and (5) imply that the optimal length of processing period ($b^* - a^*$) in each plant is where

$$F'(b) = F'(a) = k'(b - a), \tag{6}$$

which means that marginal net revenue at the commencement of the season $F'(a)$ must be equal to marginal net revenues $F'(b)$ when operations cease and must be equal to marginal processing costs $k'(b - a)$ over the entire period. These requirements depend critically upon the time-dependent behavior of sugarcane quality and volume processed each time period over the season as well as the symmetry of the total processing cost function in each time period at each plant.[4] If additional constraints are imposed such as raw product supply, seasonal processing capacities, and total industry output and if a chain of plants is considered each competing for sugarcane supplies on the basis of quality variation, then for each plant in this constrained situation marginal production costs plus the imputed values of the constraints (assuming the constraints are effective) must be equal to marginal net revenue at the end of the season.

Model Formulation

The point of departure for this study is a modification of the classical Koopman-Hitchcock

[2] The term "quality horizon" planning may be contrasted with the "cost" or "production horizon" planning problem of Modigliani-Hohn which emphasized (expected) inventory and production cost as the major determinants of optimal scheduling. Under imperfect competition, Mills has shown that the nature of the "price expectation" horizon is equally as important as production and cost elements.

[3] This form of the total processing cost function implies belief in an underlying production function in sugar milling which is temporarily homogeneous of degree one (i.e., average rate of throughput over the entire season is equal to the marginal or instantaneous rate of throughput in each time period). Many chemical extraction processes which operate continuously such as raw sugar manufacture require the maintenance of a uniform feed rate of throughput throughout the processing period; the relevant production characteristics of these processes have been described by Dano. Thus, in order to maintain a uniform rate of throughput in each weekly time period, idle or dead time varies inversely with K_t—the weekly processing capacity. The characteristics of K_t depend upon environmental phenomena and are discussed below.

[4] The symmetry of the processing cost function specified above approximates the behavior of processing costs in sugar milling in that for each time period a fixed number of skilled operators (who are hired on a seasonal basis) are required in order to maintain a uniform throughput. Thus, as millers' experience suggests, the decline in throughput K_t as the season is extended necessitates a rapid increase in marginal production costs as the terminal values of the season are approached.

transportation model used by Bishop, Bowman, and Wetzel for analyzing the deterministic production-scheduling problem of Modigliani-Hohn. The model extends a basic model developed by Guise and Ryland (1969) for analyzing production scheduling of a single plant to include the scheduling of production at a chain of plants, network flows of raw material among processing plants, and transshipment of the transformed raw material to regions of distribution.[5]

Three characteristics distinguish this approach from other production scheduling models discussed by Veinott. First is the explicit introduction of profit maximization in the objective function, and the second is the emphasis on timing of production rather than the determination of the rate of production over time. Third, because harvested sugarcane is a perishable commodity, storage is not permitted between weekly time periods which was the unit time period chosen for this study.

To formulate the model using matrix notation let: W = an $mn \times 1$ column vector of shipment quantities from supply point i to plant j; Y = an $n \times 1$ column vector of amount of sugarcane processed during the season at each of the eight plants; X = an $nT \times 1$ column vector of sugarcane processed in each week at each plant; Z = an $nq \times 1$ column vector of amount of raw sugar transshipped from plant j to terminal k; F = an $mn \times 1$ column vector of unit transport costs associated with the physical shipment of sugarcane to each plant; $P(Y)$ = an $n \times 1$ column vector of total short-run processing cost at each plant j for a production of Y_j and $P'_j(Y_j) = \partial P_j(Y_j)/\partial Y_j$ is the nonnegative marginal processing cost at plant j (the Hessian matrix formed from $P(Y)$ is assumed to be positive definite, which means that processing costs are assumed to be a monotonically nondecreasing function of throughput); T = an $nq \times 1$ column vector of the costs of shipping manufactured raw sugar from the factor to the bulk-handling terminal located at the coastal port; $Ps(\alpha - \beta)$ = an $nT \times 1$ column vector of estimated processing margin per ton of sugarcane received at plant j in each week t;[6] S = an $m \times 1$ column vector of sugarcane supplies at each supply source; K = an $nT \times 1$ column vector of processing capacities of plant j in units of sugarcane processed in each time period (in each plant, K was determined from an estimated processing capacity relationship); H = an $n \times 1$ column vector denoting the restriction on total seasonal processing capacity of the plant; and D = a single nonnegative variable representing the difference between the fixed quota on raw sugar in the region and the actual quantity of raw sugar paid for by all plants in producing the regional quota.

In addition to the above elements, the following special matrices are also used: G_1 = an $m \times mn$ matrix composed of m-adjoined submatrices each of dimension $m \times n$ in which the elements of the ith row for each of the m submatrices consist solely of 1's for $i = 1, \ldots, m$; H_1 = an $n \times mn$ matrix composed of m-adjoined sets of identity matrices each $n \times n$; G_2 = an $n \times nT$ matrix composed of n-adjoined submatrices each $n \times T$ in which the elements in the jth row for each of the n submatrices consist solely of 1's for $j = 1, \ldots, n$; H_2 = an $n \times n$ identity matrix; G_3 = an $n \times nT$ matrix similar to G_2 except that the elements are quality and extraction factors γ used for adjusting the raw sugar actually produced to account for differences in raw sugar purity; G_4 = an $n \times nq$ matrix composed of n sets of $n \times q$ submatrices in which the elements of the jth row in each of the n submatrices consist solely of 1's, $j = 1, \ldots, n$; R = an $nT \times 1$ column vector whose elements consist solely of the quality parameters $(\alpha - \beta)$.

Given these definitions and notation, the programming problem can be expressed as

$$\text{(7)} \quad \max \Phi(X, W, Y, Z) = \{Ps\ (\alpha - \beta)\}'\, X - F'W - P(Y) - T'Z,$$

subject to:

[5] In this analysis we assume that the raw material is homogeneous with respect to sugarcane quality at each supply source. Spatial and temporal differences in sugarcane quality are always reflected in the average quality of the sugarcane at each plant location. From the viewpoint of the processing sector, spatial and temporal differences in sugarcane quality at each supply source is of limited practical relevance as growers usually receive a constant premium or discount for percentage movements in quality up or down relative to the mill weekly average quality.

[6] The fixed return of sales of raw sugar 94 net titre subject to quota is Ps, while α and β are the quality and extraction factors; $P_s\beta$ is the grower's return per ton of sugarcane established by institutional arrangements where $\beta = 0.009$ (CCS − 4) and α = 0.0001 CW CCS where both CCS and CW are expressed in percentage terms. In the above relationships, $Ps\beta$ also includes a constant term of $0.3333 which for ease of exposition is omitted from the model, but it was included in formation of weekly net revenue per ton of sugarcane processed each week. The term CW refers to the coefficient of work or index of extraction efficiency at each plant. It relates the amount of raw sugar recovered from the sugarcane to the amount of sugarcane it is theoretically possible to recover. Under normal circumstances a figure of 97.5% is typical of the extraction performance at Queensland sugar mills.

$$(8)\quad G_1 W \leq S\ ;u,$$

$$(9)\quad -H_1 W + Y^{*} \leq 0\ ;v,$$

$$(10)\quad -H_2 Y + G_2 X \leq 0\ ;\eta,$$

$$(11)\quad X \leq K\ ;\lambda,$$

$$(12)\quad G_3 X - G_4 Z \leq 0\ ;\epsilon,$$

$$(13)\quad Y \leq H\ ;\omega,$$

$$(14)\quad R'X \leq D\ ;g,$$

and

$$(15)\quad W, Y, X, Z \geq 0.$$

The problem stated in Lagrangean form is

$$(16)\quad \max \pi(X, W, Y, X, u, v, \lambda, \eta, \epsilon, \omega, g) = \{Ps\ (\alpha - \beta)\}'\ X - F'W - P(Y) - T'Z + u'\ (S - G_1W) + v'\ (H_1W - Y) + \eta'\ (-H_2Y + G_2X) + \lambda'\ (K - X) + \epsilon'(G_4Z - G_3X) + \omega'(H - W) + g'\ (D - R'X),$$

subject to

$$(17)\quad X, W, Y, Z, u, v, \eta, \lambda, \epsilon, \omega, g \geq 0.$$

The Kuhn-Tucker necessary conditions for a maximum of equation (16) can be stated as follows:

$$(18)\quad \frac{\partial\pi}{\partial X} = Ps\ (\alpha - \beta) + G'_2\,\eta - \lambda - G'_3\,\epsilon - Rg \leq 0; \left(\frac{\partial\pi}{\partial X}\right)' \cdot X = 0,$$

$$(19)\quad \frac{\partial\pi}{\partial W} = -F - G'_1\,u + H'_1\,v \leq 0; \left(\frac{\partial\pi}{\partial W}\right)' \cdot W = 0,$$

$$(20)\quad \frac{\partial\pi}{\partial Y} = -P'\ (Y) + v - H'_2\,\eta + \omega \leq 0; \left(\frac{\partial\pi}{\partial Y}\right)' \cdot Y = 0,$$

$$(21)\quad \frac{\partial\pi}{\partial Z} = -T + G'_4\,\epsilon \leq 0; \left(\frac{\partial\pi}{\partial Z}\right)' \cdot Z = 0,$$

$$(22)\quad \frac{\partial\pi}{\partial u}, \frac{\partial\pi}{\partial v}, \frac{\partial\pi}{\partial\eta}, \frac{\partial\pi}{\partial\epsilon}, \frac{\partial\pi}{\partial\omega}, \frac{\partial\pi}{\partial g} \geq 0,$$

and

$$(23)\quad \left(\frac{\partial\pi}{\partial v}\right)' v = \left(\frac{\partial\pi}{\partial u}\right)' u = \left(\frac{\partial\pi}{\partial\eta}\right)' \eta = \left(\frac{\partial\pi}{\partial\lambda}\right)' \lambda = \left(\frac{\partial\pi}{\partial\epsilon}\right)' \epsilon = \left(\frac{\partial\pi}{\partial W}\right)' W = \left(\frac{\partial\pi}{\partial g}\right)' g = 0.$$

Equations (18)–(23) are both necessary and sufficient for an optimal solution of the maximization problem in equations (8)–(15) if the objective function is concave and the constraints are convex. All terms other than $P(Y)$ in the maximization problem in equations (7)–(15) are linear and hence are both convex and concave. To assure a maximum in addition to the necessary conditions in equations (18)–(23), the sufficient condition is that the Hessian matrix $\frac{\partial^2\pi}{\partial^2 Y}$ is negative definite. As the Hessian matrix $\frac{\partial^2 P(Y)}{\partial^2 Y}$ is positive definite, by assumption, the sufficient condition always holds and a global maximum can always be determined.

Rewriting the dual constraint set, equations (18)–(21), component-wise and using the primal-dual relationships, it is possible to deduce equivalent symbolic expressions for quality equilibrium as those derived previously as follows:

$$(24)\quad \text{if } X_{ij} > 0, \eta_j + \lambda_{ij} + \epsilon_j\gamma_{ij} + g(\alpha_{ij} - \beta_{ij}) = Ps\ (\alpha_{ij} - \beta_{ij});$$

$$(25)\quad \text{if } W_{ij} > 0, F_{ij} + u_i = v_j;$$

$$(26)\quad \text{if } Y_j > 0, P'_j(Y_j) + v_j + \omega_j = \eta_j;$$

and

$$(27)\quad \text{if } Z_{jk} > 0, t_{jk} = \epsilon_j.$$

Combining equations (25) and (26) and then making the necessary substitutions for η_j and ϵ_j in equation (24), the requirements for the optimum length of quality horizon in each plant can now be stated as

$$(28)\quad Ps(\alpha_{ij} - \beta_{ij}) = P'_j(Y_j) + F_{ij} + u_i + \omega_j + \gamma_{ij}t_{jk} + \lambda_{ij} + g(\alpha_{ij} - \beta_{ij}).$$

Equation (28) is the programming model's analogue of equation (6). It simply states that provided production is positive, the processor's margin or marginal net revenue is equal to marginal production cost over each production interval in each plant. In the discrete time period programming formulation, explicit consideration is given to supply and capacity factors which may effectively bind production in each time period at each plant location. When the only effective constraint is processing capacity in each time period, i.e., $\mu_i = \omega_j = g = 0$, equation (28) reduces to

$$(29)\quad Ps(\alpha_{ij} - \beta_{ij}) = P'_j(Y_j) + F_{ij} + \lambda_{ij} + t_{jk}\,\gamma_{ij}.$$

Using equation (29), it is possible to deduce alternative market configurations. Relaxing the time element in equation (29), gives the condition for an unconstrained optimum in each plant under spatial quality competition. In equation (30),

$$(30)\quad Ps(\alpha_j - \beta_j) = P'_j(Y_j) + F_{ij} + \gamma_j t_{jk},$$

marginal net revenue and marginal sugar transportation costs at each plant vary over some predetermined time interval according to the average level of the quality parameters $(\alpha_j - \beta_j)$ and γ_j in each plant respectively. One extreme form of the market is pure competition. A necessary assumption is that the product is homogeneous, i.e., $(\alpha_1 - \beta_1) = , \ldots , = (\alpha_n - \beta_n)$ and $\gamma_1 = , \ldots , = \gamma_n$. Assuming homogeneous sugarcane inputs, equation (30) reduces to the purely competitive equilibrium solution for each plant:

$$(31)\quad Ps(\alpha - \beta) = P'_j(Y_j) + F_{ij} + t_{jk}\gamma.$$

Under pure competition, marginal net revenues are equal in all plants and the only requirement for partial competitive equilibrium is that marginal production costs at all plant locations must be equal.

One further condition that can now be stated explicitly using equation (29) is the condition for exchange equilibrium under imperfect competition. Transfer shipments of sugarcane can only take place between source i and plant j if the transportation cost of the raw product from i to j is less than or equal to the difference between marginal net revenue and marginal production cost at plant j.

In terms of equation (29), this requirement can be stated as

$$(32)\quad F_{ij} \leq [Ps(\alpha_{ij} - \beta_{ij})] - \mu_i - \omega_j - \lambda_{ij} - t_{jk}\gamma_{ij} - g(\alpha_{ij} - \beta_{ij}), \quad \text{for} \quad i \neq j.$$

The mathematical programming problem in equations (7)–(15) would be linear if it were not for the specification of a quadratic processing cost function in each plant for each processing season. We utilized conventional concave separable programming techniques using Hadley's method of imposing upper bounds on each production interval throughout the cost domain of interest in each plant so as to obtain a piece-wise linear approximation to the concave programming problem. In addition, as the internal structure of the programming model in equations (7)–(15) bears a close relationship with the linear programming format of the classical Hitchock-Koopmans transportation problem, which was shown by Williams to be amenable to decomposition, the Dantzig-Wolfe decomposition algorithm was utilized to provide a solution to the problem with much less computational effort than would be required if an attempt was made to solve the problem in its entirety.

Discussion of Results

Using the above model, we have analyzed three forms of nonprice competition for allocating production quotas among sugarcane processors in the Australian sugar industry at the regional level.[7] In the sugar industry, the processor is physically and financially responsible for the scheduling and collection of harvested sugarcane. Supplies of sugarcane are usually assembled by growers at sidings located along narrow gauge tramway networks, and from here sugarcane is transported to the mill for processing. A total of 530 supply points were identified in the study region and 1076 transportation routes were utilized which includes a total of 546 feasible interplant shipment possibilities. For each feasible route, unit sugarcane transportation costs from each supply point to the mill and unit sugarcane transfer costs to adjacent mills were determined. At each of the eight plants, a short-run processing cost function was estimated using least-squares regression applied to data analyzed by Ryland (1969). Unit freight charges on raw sugar from each sugar factory to the bulk terminal were assessed depending on the mode of transport currently in use.

These physical data and cost elements provided the input for the model to determine the purely competitive quota allocation outlined in equation (31) above including any effective constraints. The conversion ratio between sugarcane and manufactured raw sugar was determined as the regional average over the single season at all plants to conform with the

[7] The area in which the empirical work was carried out is a quite well defined sugar-producing region located on the northern coastal lowlands of Queensland, known as the Central Sugar District, and does not adjoin any other sugar-producing region. It comprises an area of approximately 11,000 square kilometers with approximately 70,000 hectares under sugarcane in 1974 producing in excess of 800,000 tons of cane sugar, illustrative of the intensity of the monocultural activity carried on. The sugar industry is government regulated with each processing plant allocated a fixed output each year, the mechanics of which have recently been discussed by Ryland (1973). We assume that the processors pool their quota to form a regional quota and allow interplant shipments of raw material so as to break the traditional monopsony between processors and suppliers.

product homogeneity and equality of marginal revenue requirements of pure competition.

In the sugar industry, growers receive payment for sugarcane according to a sliding scale payment scheme which is based on the theoretical amount of CCS in a sample of the juice from freshly crushed sugarcane and average returns from sales of raw sugar in quota production. The prices received for raw sugar are the same at all plants but the average quality of the CCS differs among plants. Consequently, the revenue received by the processor for each ton of sugarcane processed after deducting payment to growers reflects differences in CCS at each plant. When the marginal revenues received by the processor at each plant are included in the model, the monopolistic solution which results is referred to as spatial quality competition and (in the absence of binding constraints) is expressed in equation (30).

Apart from the trend component, the shape of the series of average sugarcane quality processed in each weekly time period at each plant follows a repetitive seasonal pattern in normal years (Ryland 1975). In addition, estimates of plant processing capacity each week were based on the hypothesis that the amount of sugarcane processed each week followed a distinct parabolic time trend similar in form to that of average sugarcane quality. While there is no reason, theoretically at least, to support such an hypothesis as plant capacity should remain constant over the season, the increased likelihood of wet weather at the terminal dates of the season inhibits mechanical harvesting operations, thereby creating insufficient supplies of sugarcane at the plant. When both these biological and environmental elements are introduced into the model, we can use the production principles outlined above to obtain the requirements for the optimum length of processing period in each plant necessary to produce the target production which is expressed in equation (28) above.[8] Solutions to the three forms of nonprice competition for allocating the given target production were compared with the actual net revenues of industry organization for the particular sugar-producing region in the 1966 season and these are summarized in table 1. From table 1, the following points can be made. An increase in annual net revenue of over $175,060 by simply maximizing industry net returns assuming homogeneous sugarcane inputs is certainly worthwhile. The actual net revenues represent approximately 97.6% of the net revenues of optimal allocation which is a slight departure from the potential industry realizations indicated by the competitive model. Perhaps more significant in terms of the effect on actual net revenues is the solution obtained when sugarcane is differentiated according to vertical quality height at each plant. In this situation, actual regional net revenues are only 90.8% of the net revenues of optimal allocation. Revenues are $539,295 above those in the competitive situation. This figure provides a measure of the latitude of spatial monopoly due to quality differences only. Total exploitation of differences in the sugarcane quality cycle over time and among plant locations to produce the target sugar production results in an increase in annual regional net revenues of approximately $950,000. This particular solution represents an increase in revenue of $236,684 relative to the spatial quality situation that could be

[8] Input quality differences could also be incorporated as cost differentials and in this form the total cost minimization approach is equally valid in cartel-type industry organizations of the type considered in this study.

Table 1. Increase in Industry Net Revenue from Regional Quota Allocation Using Various Forms of Nonprice Competition

Economic Environment	Quantity of Sugarcane Requiring Processing (tons)	Increase in Net Revenue Compared with Actual Net Revenue (Australian $)	Actual Net Revenue as Percentage of Optimum
Pure competition	3,899,712	175,060	97.6
Spatial quality competition	3,716,456	714,355	90.8
Spatiotemporal quality competition	3,868,021	951,039	88.2

earned annually by simply adopting the optimal scheduling pattern.

For each plant, the optimal crushing period indicated a later start-up time of late July–early August compared with the actual earlier start-up schedule in 1966 of late May–early July. The difference between this production pattern and that given in the solution to the model suggests that the choice of an optimum production period is of little real practical importance to mill management. The optimal solution revealed, however, that the average intramarginal value of sugarcane processed in each time period over all plants (the dual solution vector λ) together with the average marginal cost in terms of revenue foregone of the early start schedule would increase costs by an average of 15¢ per ton plus an additional 5¢ per ton from processing the additional volume of sugarcane for each week that the optimal schedule was brought forward. In addition, the optimal scheduling pattern remains reasonably stable for a range of prices for quota sugar but is extremely sensitive to parametric variation in sugarcane quality.[9]

Perhaps more important is the effect on the break-even value for production of above-quota sugar in the three economic evironments. This is given by the value of the dual vector g in each optimal solution which is the marginal value to the sugar-processing industry of an additional ton of raw sugar quota given the assumed quota price of $86.50 per ton. The difference between the quota price and the value of g in each competitive environment may be interpreted as the minimum price at which it would become even marginally profitable to produce above-quota sugar.

Table 2 gives the break-even values and the processor's share of raw sugar production in each of the three economic environments. While this particular set of break-even values is well below current export prices for raw sugar, it does indicate that substantial marginal economic losses were incurred by processors producing above-quota sugar in the period 1965–70 in which period export returns averaged only approximately $40 per ton. Another interesting analysis may be made

Table 2. Effect of the Various Forms of Nonprice Competition on Break-Even Price and Volume of Raw Sugar Actually Received by Processors

Economic Environment	Processor's Share of Quota Production (tons)	Break-Even Value of Above-Quota Sugar (Australian $)
Pure competition	176,165	68.69
Spatial quality competition	177,560	72.13
Spatiotemporal quality competition	186,398	75.5

when the volume of sugarcane processed in table 1 is compared with the share of raw sugar output received by processors in table 2 for each of the three economic environments. Although the production-scheduling model solution requires 151,565 tons of sugarcane more than the spatial quality solution in order to produce the same level of output, the extra costs associated with processing the additional volume of sugarcane are more than offset by the extra revenue received by processors from the additional increase of 8,838 tons of raw sugar in the processors' share of raw sugar output. The reduction in average sugarcane quality associated with the regional production-scheduling solution relative to the timeless spatial solution implies that, as sugarcane quality increases, the marginal costs of purchasing sugarcane and effectively binding throughput to periods of higher quality tend to negate any marginal cost advantages of processing and transporting the smaller quantity of sugarcane inputs required to produce the given output of raw sugar.[10]

These empirical findings serve to point up substantial losses in annual industry revenue and in social efficiency which can be traced to the institutionalized methods used for allocating production quotas in this region. The capitalized value of the regional net revenue increases which would accrue from adopting

[9] A $1.00 increase in raw sugar prices increases net revenue by approximately 4¢ per ton of sugarcane processed. On the other hand, a 1% increase in sugarcane quality delays the start of the processing season by approximately one week in each mill area, increases net revenue per ton of sugarcane processed by 6.6¢ and reduces the volume of sugarcane processed, for given output, by approximately 125,000 tons.

[10] Elsewhere we have demonstrated (Guise and Ryland 1971) that the existing formula for sugarcane payments in the Australian sugar industry (footnote 6) mitigates against millers adopting the most economically efficient scheduling practices. The formula shows that, from the viewpoint of the processor, the marginal costs of recovering sugar from sugarcane of higher quality do not decline as fast as the marginal revenue to the miller from processing sugarcane of higher quality. To overcome this anomaly we have suggested that the processor obtain a constant share of percentage changes in sugarcane quality sufficient to compensate him for the loss in marginal net revenue as quality increases.

some form of quality competition as a means of allocating the industry's target production in this region establishes an upper limit to the provision of transport equipment necessary to effect the changes indicated in spatial organization and the level of transfer payments which could be used by the industry to assist those growers who lose quota rights to move out of sugar production entirely.

Conclusions

For a regulated industry organization where the final product can be regarded as homogeneous, where product prices are determined exogenously, and where the inputs span a range of feasible qualities, we have formulated an activity-analysis model which is used to analyze under varying degrees of competition the effect on industry net revenues of explicitly incorporating basic differences in input quality. The divergence which emerges in net industry revenues between each economic environment arises as a result of exploiting the higher quality ranges of the input. When both temporal and spatial differences in input quality are included, the model determines, for given output, the optimum production schedule at a chain of sugarcane-processing plants.

It is not possible to claim, however, that the optimal solution obtained using this model has solved the sugar industry's recurring planning problem in the Modigliani-Hohn sense. The series of sugarcane quality and processing capacity require further analysis to determine their interseasonal behavior. The specification of a Box-Jenkins dynamic seasonal model of the type recently discussed by Ryland (1975) is one promising avenue for further research. Using the forecasts obtained for these physical relationships and assuming a range of expected prices for raw sugar, the model could then be used for purposes of *ex ante* production planning for the following season as well as for adaptively revising single season plans, as time passes and more information becomes available.

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Optimizing Seed Acreage: Decision Making with Production and Utilization Uncertainties

M. Dean Ethridge, Fred C. White, and D. Kannan

Under yield and utilization uncertainties, optimum planted acreage may be estimated using the concept of disequilibrium costs—those costs incurred when production is not matched with utilization. A model to minimize expected disequilibrium cost is formulated and applied to peanut seed acreage in Georgia. Since larger disequilibrium costs result from underproduction than from overproduction of peanut seed, optimum seed acreage increases substantially when allowances are made for existing yield and utilization uncertainties.

Key words: optimum acreage, uncertainties, disequilibrium costs, peanut seed.

The task of estimating appropriate acreage to plant in a given crop is of vital concern to agricultural producers and policy makers. The difficulty of doing this is compounded by the fact that both per acre yield and total utilization of an agricultural commodity are usually subject to substantial random variation around their expected values.

Even if all production and marketing activities are performed in an economically efficient manner, added costs are incurred if actual production does not equal actual utilization.[1] These costs may be termed "disequilibrium costs" or simply "additional costs." Thus, by definition, if actual production is equal to actual utilization, disequilibrium cost is zero. It is incurred only by failing to perfectly match production with utilization.[2]

This paper presents a theoretical framework for estimating planted acreage that will minimize the expected value of disequilibrium costs resulting from failure to equate total production with total utilization, with application made to peanut seed acreage in Georgia. Although subjected to limited analysis by economists, seed is an important farm input to commercial agriculture, which increasingly relies on an organized seed industry to supply high quality seed of known variety.

Much of the existing literature on economic decisions under uncertainty deals with individual choice among various economic ventures over time, rather than among alternatives within a single venture (e.g., Arrow, Fama, Hadar and Russell, Hildreth, Zabel). More relevant to this analysis is the theory of inventory management (e.g., Hadley and Whitin, Schlaifer). Agricultural applications of decision making under climatic uncertainty have been made in estimating optimum livestock feed reserves (Candler; Afzal, McCoy, and Orazem). de Janvry's optimization of fertilization levels is a more recent application. (For additional discussion and references, see Drèze, and Halter and Dean.) The analysis in this paper is distinct in its attempt to optimize quantity of the land resource under production and utilization uncertainties.

Analytical Framework

Seed is a farm input that is produced as well as used by farmers. Supplies of such inputs—unlike agricultural chemicals, fertilizers, fuels, and machinery—are subject to significant random fluctuations due to weather, disease, and insects. This is especially true for seeds, which are living organisms and are therefore quite susceptible to destruction.

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[1] Utilization may be specified to include more than just consumption in the market place; e.g., it may include desired levels of stocks, disaster relief grants, etc.

[2] The disequilibrium cost could conceivably be formulated for producers, marketing sectors, the entire agricultural sector, etc.—depending on a researcher's area of interest.

Just as seed supplies are subject to random yield fluctuations, seed demanded by farmers to plant a given acreage may also vary widely due to replantings occasioned by environmental conditions. Thus, matching quantities supplied with quantities demanded of a particular seed is an uncertain task at best. This uncertainty undoubtedly results in increased costs to the agricultural sector.

Sources of Disequilibrium Costs

Peanut seed produced in the current season will be used to plant the crop for next season. (Rarely are they carried over for two seasons because of prohibitive storage costs and/or deterioration of seed quality.) A state's agricultural sector incurs additional costs whenever production of high quality seed in the current year is not equal to seed utilization in the following year. Costs associated with not having the desired quantity of seed may arise from three sources.

First, more seed may have been produced than desired for storage. More seed may be produced than is expected to be required next year, due to a larger seed yield per acre than anticipated. In this case the extra seed is sold in the edible peanut market and additional costs are incurred because production for seed is more expensive than production for edible purposes.

Second, there may be too much seed at planting time. In this case, expected seed requirements have been overestimated and too much seed was processed and stored. If extra seed is sold on the edible market at this time, additional costs have been incurred for production, processing, and storage.

Third, there may not be enough seed at planting time. In this case, not enough seed was processed and stored to meet seed requirements. This may be due to overestimation of per acre seed yield and/or underestimation of per acre seed utilization. To make up for the shortage of high quality seed, the industry must either ship seed in from outside the state or resort to lower quality seed obtained from peanuts not produced specifically for seed purposes. Having to ship seed into the state results in additional out-of-pocket costs.[3] Use of lower quality seed will increase costs because of reduced peanut yields, increased planting rates in order to get an acceptable stand of plants in the field, and additional cultivation, herbicides, or other treatments to reduce competition with the less vigorous plants.

For a fixed peanut acreage, alternative seed acreages result in distinct probabilities of incurring costs from each of the foregoing sources. The task is to determine optimum seed acreage, i.e., the seed acreage for which expected disequilibrium cost is minimized.

The Model

Seed production and utilization. Quantity of seed produced in year t is given as

$$(1) \qquad P_t = A_t Y_t = A_t(\bar{Y}_t + e_1),$$

where P is seed production, A is acreage planted for seed, Y is seed yield per acre, $\bar{Y}$ is expected seed yield per acre, t is the current year, and e_1 is a random variable associated with the randomness of yield. Thus, actual seed production is a function of planted acreage and the random variable yield.

If actual seed production is greater than quantity of seed needed to minimize expected cost, then excess seed production is sold in the edible market:

$$(2) \qquad SE_t = \begin{cases} P_t - P^*_{t+1} \text{ if } P_t > P^*_{t+1} \\ 0 \text{ otherwise,} \end{cases}$$

where SE is quantity of seed sold in edible market and P^*_{t+1} is quantity of seed that minimizes expected cost in year $t + 1$. The quantity P^*_{t+1} minimizes expected disequilibrium cost in the presence of utilization uncertainty only. Since total quantity of seed (rather than total seed acreage) is considered when estimating P^*_{t+1}, the per acre yield uncertainty is not applicable.[4]

The quantity of seed stored for next season's planting is equal to seed production unless some is sold in the edible market due to overproduction:

$$(3) \qquad SS_t = P_t - SE_t,$$

where SS is quantity of seed stored.

Total seed utilization is given by

$$(4) \quad U_{t+1} = u_{t+1} AP_{t+1} = (\bar{u}_{t+1} + e_2) AP_{t+1},$$

[3] Of course some peanut seed are brought into, as well as shipped out of, the state in a normal year. To the extent that this is planned by the industry, no additional costs are assumed to occur. When unplanned, however, the agricultural sector must bear at the very least some additional shipping costs.

[4] Thus, the level of P^*_{t+1} is estimated in the same fashion as the optimum level of planted acreage (see the estimation procedure section), the difference being that only one source of uncertainty is considered.

where U_{t+1} is total peanut seed used in year $t+1$, u is seed utilization per acre planted, AP is planted acreage of peanuts for food, $\bar{u}$ is expected seed utilization per acre planted, and e_2 is a random variable associated with number of times planted. Thus, per acre seed utilization is assumed to be unaffected by seed price.[5] It is systematically related only to the planting rate.

Costs to the agricultural sector. If seed production is greater than the quantity which minimizes expected costs ($P_t > P^*_{t+1}$), the additional production cost for the excess seed is given by

$$(5) \qquad C_1 = GR\,(P_t - P^*_{t+1})/Y_t,$$

where C_1 is additional cost of production for excess seed, and GR is additional growing cost per acre (i.e., additional cost of producing for seed rather than for food).

If quantity of seed stored is greater than seed utilization, added cost is given by

$$(6) \qquad C_2 = (GR/Y_t + PS)\,(SS_t - U_{t+1}),$$

where C_2 is additional cost for seed kept over until next season, and PS is processing and storage cost per pound of seed.

If quantity of seed stored is less than seed utilization, added cost is given by

$$(7) \quad C_3 = \bar{E}_{t+1}\,(\Delta\cdot\overline{YP}_{t+1})\,\frac{U_{t+1} - SS_t}{\bar{u}_{t+1}} + GC\left(\Theta\frac{U_{t+1} - SS_t}{\bar{u}_{t+1}}\right) + CI[\Phi(U_{t+1} - SS_t)],$$

where C_3 is additional cost of not having enough high quality seed, $\bar{E}_{t+1}$ is expected peanut price in edible market year $t+1$, Δ is proportionate decrease in peanut yield per acre due to low quality seed, $\overline{YP}_{t+1}$ is expected peanut yield per acre in year $t+1$, GC is additional growing cost per acre due to low quality seed, Θ is proportion of acres planted with low quality seed, CI is additional cost per pound of inshipping extra seed, and Φ is proportion of deficit seed inshipped.

Costs C_1 and C_2 are incurred only if "overproduction" of seed occurs, while C_3 is incurred only if "underproduction" of seed occurs. However, C_1 and C_2 are not necessarily incurred together. If $P_t > P^*_{t+1}$, then the quantity $SE_t = P_t - P^*_{t+1}$ is sold on the edible market and the cost C_1 is absorbed. After this is done, there is an equal probability of incurring either C_2 or C_3. The sequential nature of the decision process must be simulated when deriving expected disequilibrium cost for a given seed acreage.

Conceptual Analysis

The following presentation abstracts from time and thereby circumvents complications of a sequential decision process. The purpose is to simplify the empirical model in order to gain accurate insights about its application.

For a given crop, A = planted acreage, Y = yield per acre, $P = A\cdot Y$ = total production, U = total utilization, and $X = P - U$ = excess production:

$$(8) \quad C(X) = \begin{cases} \alpha X;\ X > 0,\ \alpha > 0 \\ 0;\ X = 0 \\ -\beta X;\ X < 0,\ \beta > 0 \end{cases} = \text{cost of } X,$$

where α and β are unit cost coefficients for overproduction and underproduction, respectively.[6]

Assuming Y and U are independent random variables with normal distributions,[7]

$$(9) \quad Y \sim N(\mu, \sigma^2),\ U \sim N(\nu, \delta^2),\quad \mu, \sigma^2, \nu, \delta^2 > 0.$$

Since Y and U are independent, it follows that X is also a normally distributed random variable:

$$(10) \quad X \sim N(A\mu - \nu,\ A^2\sigma^2 + \delta^2).$$

The relationships among acreage, excess production, and additional cost are illustrated by a three-dimensional graph (figure 1). Acre-

[5] This assumption was upheld by trial regressions of per acre peanut seed utilization on peanut seed price. Since peanuts are grown on a limited acreage and are a highly valued crop, it is reasonable to conclude that the derived demand for peanut seed is almost perfectly inelastic with respect to its own price.

[6] Formulating additional cost as a polygonal function of excess production is somewhat arbitrary, but more general functions could be used if appropriate.

[7] Because events leading to the random variations in yield are distinct and independent from those causing random variations in utilization, it is reasonable to assume that Y (hence P) and U are independent random variables.

It is also reasonable to assume that P and U are normally distributed. For example, P is determined from per acre yields on a large number of acres; hence, it is the sum of a large number of independent and uniformly bounded random variables. Appealing to the central limit theorem (cf., Fisz, p. 206), one can take P as a Gaussian (normal) variable. Similar reasoning applies for U.

For an alternative justification of the normality assumption, one may observe that X is the random error made in matching production with utilization. Therefore, the error function, i.e., the normal density, may be used to describe X (cf., Johnson and Kotz). Since P and U are independent and $X = P - U$ is normally distributed, by Cramer's theorem (cf., Fisz, p. 150), P and U are also normally distributed random variables.

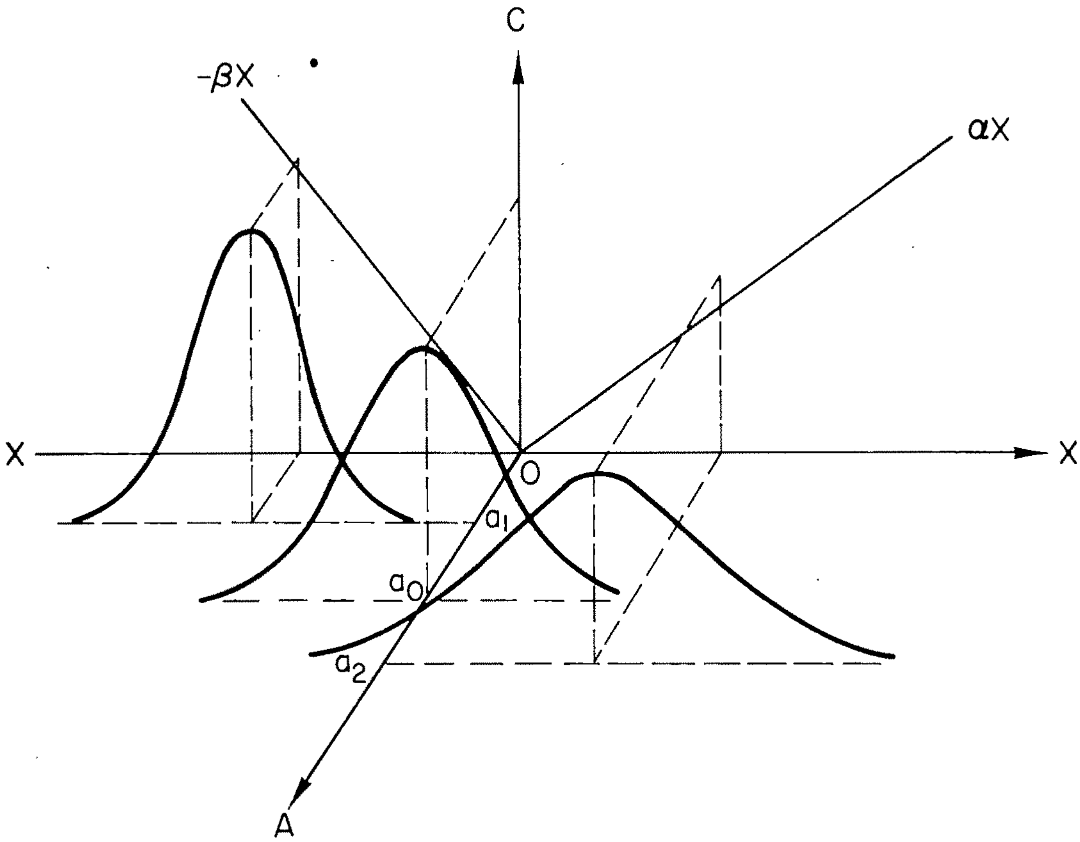

Figure 1. Relationships among additional cost (C), excess production (X), and acreage (A)

age and additional cost are nonnegative while excess production may be positive (if production is greater than utilization) or negative (if production is less than utilization). For any given acreage there is an expected value of excess production and a distribution around the expected value. Figure 1 illustrates a fact that follows from equation (10); an acreage increase causes both the mean and variance of excess production to increase. For $A = a_0$, the expected value of excess production is zero; i.e., $E(X) = 0$. For $A = a_1$, $E(X) < 0$ and for $A = a_2$, $E(X) > 0$.

Under the specified assumptions, expected disequilibrium cost $E(C)$ is given as follows:

$$(11)\quad E(C) = \int_{-\infty}^{\infty} C(x) f(x)\, dx$$

$$= \int_{-\infty}^{\infty} \frac{C(x)}{\sqrt{2\pi (A^2\sigma^2 + \delta^2)}} \exp\left[-\frac{(x - A\mu + \nu)^2}{2(A^2\sigma^2 + \delta^2)}\right] dx$$

$$= \frac{1}{\sqrt{\pi}} \left\{ \frac{(\alpha + \beta)\sqrt{A^2\sigma^2 + \delta^2}}{\sqrt{2}} \exp\left[-\frac{(A\mu - \nu)^2}{2(A^2\sigma^2 + \delta^2)}\right] + \frac{\sqrt{\pi}}{2}(\alpha - \beta)(A\mu - \nu) + (\alpha + \beta)(A\mu - \nu) \int_0^{\frac{A\mu - \nu}{\sqrt{2(A^2\sigma^2 + \delta^2)}}} e^{-z^2}\, dz \right\}.$$

Equation (11) is useful in at least two ways. If the theoretical results about $E(C)$ agree with empirical data, then applicability of the model is strengthened. Also, if the model seems appropriate, then it may be used as an analytical tool when hypotheses are difficult to verify empirically.

Figure 2 illustrates determination of the expected additional cost curve. The graph is reduced to two dimensions by omitting the A axis and simply matching each acreage with the appropriate distribution on the X axis. For a given A value, integration of the product of the probability of each X value with its corresponding additional cost, equation (11), yields expected additional cost for that acreage, giving one point on the $E(C)$ curve in figure 2.

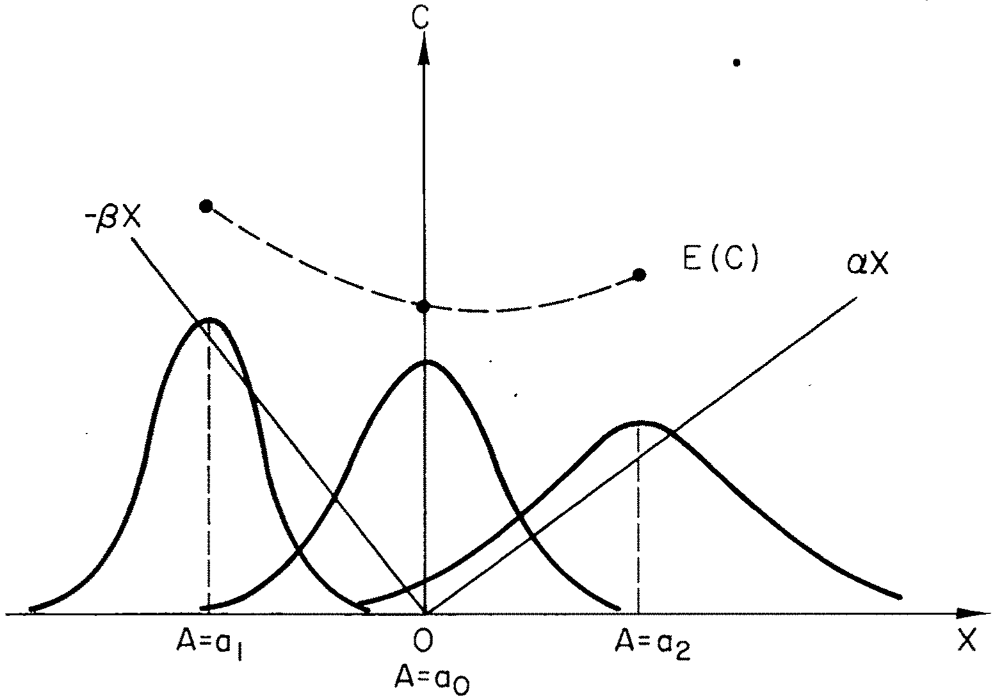

Figure 2. Determination of expected additional cost $E(C)$ of excess production for various acreages

If the foregoing process is repeated for a sufficiently large number of A values, the entire $E(C)$ curve may be traced. Due to nonzero variances of production and utilization, the expected additional cost curve will always lie above the additional cost polygon. The more pertinent concern to the agricultural sector is the acreage at which $E(C)$ is minimized.

The conventional calculus method of locating the acreage which minimizes $E(C)$ may be obtained by taking the first derivative of equation (11) with respect to A, setting it equal to zero, and solving for optimum A. In this case, the first derivative of $E(C)$ with respect to A yields cubic polynomials in A with coefficients containing four arbitrarily fixed positive parameters (μ, ν, σ^2 and δ^2), and numerical methods are more appropriate to locate the optimum A value. Use of electronic computers allows numerical approximation of $E(C)$ to any desired degree of accuracy, so that behavior of cost-minimizing acreage may be observed with various values of the parameters.

Figure 3 illustrates the behavior of $E(C)$ and optimum acreage as the cost parameters α and β vary, given that the sum of α and β is a constant. It is presented primarily to clarify the systematic nature of $E(C)$ as cost specifications are systematically varied. For $E(C)_1$, $\alpha = 2\beta$, so that underproduction by a given amount is only half as costly as overproduction by the same amount. The opposite situation ($2\alpha = \beta$) is shown by $E(C)_3$. For $E(C)_2$, $\alpha = \beta$, so that underproduction and overproduction are equally costly. Intersection of the three expected additional cost curves locates the acreage A^* ($= \nu/\mu$) for which expected value of excess production is zero; i.e., $E(X) = 0$.[8] Furthermore, to the left of this acreage $E(X) < 0$, and $E(C)_1 < E(C)_2 < E(C)_3$ for any $A < A^*$. To the right of this acreage $E(X) > 0$, and $E(C)_3 < E(C)_2 < E(C)_1$ for any $A > A^*$. It follows that minimum $E(C)_1$ occurs at a smaller acreage than minimum $E(C)_2$, which in turn occurs at a smaller acreage than minimum $E(C)_3$ (i.e., $A_1 < A_2 < A_3$ in fig. 3).

Figure 3 also illustrates a fact that may not be realized at first: cost minimizing acreage where $\alpha = \beta$ does not simply occur at the acreage for which $E(X) = 0$ (i.e., where $A = A^* = \nu/\mu$). Instead it will occur at a smaller acreage than this due to the fact that by reducing acreage, variance of production

[8] This may be verified by observing from equation (11) that $E(X) = A\mu - \nu = 0$ implies $E(C) = \frac{(\alpha + \beta)\sqrt{A^2\sigma^2 + \delta^2}}{\sqrt{2\pi}}$. Therefore, if $(\alpha + \beta)$ is constant, then $E(C)$ is also constant, regardless of the relative magnitudes of α and β.

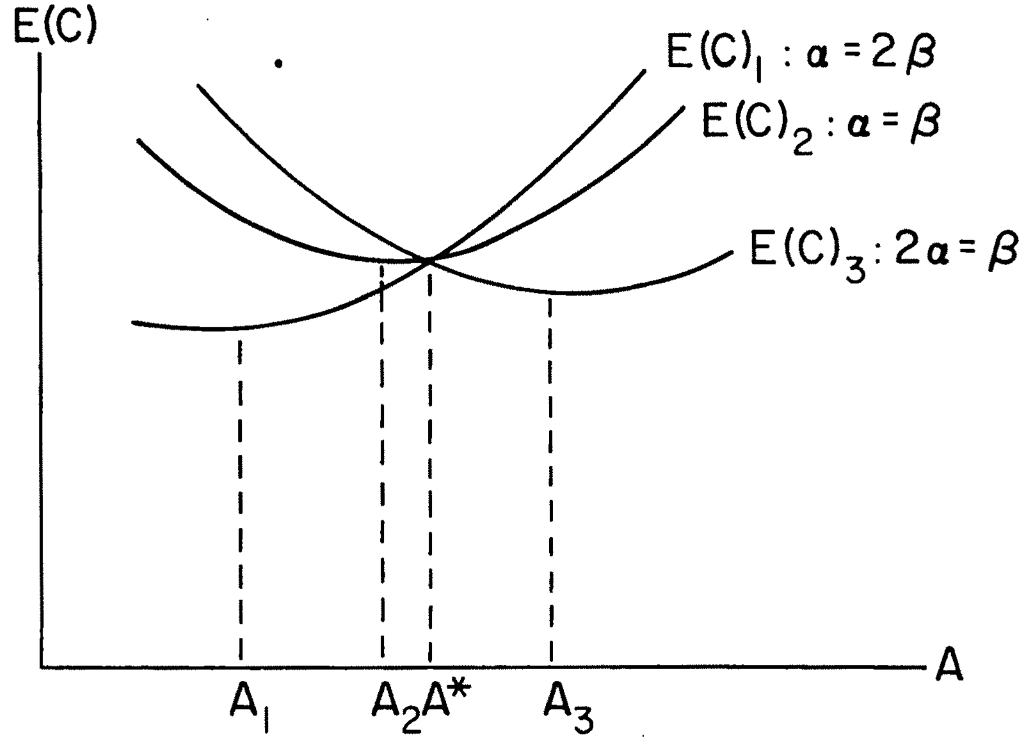

Figure 3. Behavior of $E(C)$ for various values of α and β, given that $\alpha + \beta$ is a constant

($= A^2\sigma^2$) is reduced, which will initially result in a lowering of expected additional cost.[9]

Figure 4 illustrates, for $\beta > \alpha$ (i.e., underproduction more expensive than overproduction), how $E(C)$ varies with different degrees of uncertainty. Complete certainty ($\sigma^2 = \delta^2 = 0$) results in $E(C)_1 = C$. Introducing a utilization uncertainty ($\sigma^2 = 0$, $\delta^2 > 0$) results in $E(C)_2$. Adding a yield uncertainty ($\sigma^2 > 0$, $\delta^2 > 0$) gives $E(C)_3$. Inclusion of additional uncertainties causes the $E(C)$ curves to shift successively upward and, since $\beta > \alpha$, optimum acreage to shift successively to right (from A_1 to A_2 to A_3).[10]

Application to Peanut Seed Acreage

This section demonstrates the estimation of peanut seed acreage in Georgia that would minimize expected disequilibrium costs accruing to the state's agricultural sector from production of a given peanut crop acreage.[11] There are three major types of peanuts grown in Georgia—runner type, Spanish type, and Virginia type—and results were obtained for each of these.[12]

The Data

Table 1 summarizes all variables that are exogenous to the decision model. Estimated values for seed acreage (A_t) and peanut acreage (AP_{t+1}) are not included because A_t is the decision variable and AP_{t+1} may be predetermined at an appropriate level.

Regression analysis was used to obtain expected utilization and price values. In these cases, time-series data covering the period 1963–72 were used. Where more general data were not available on production practices, yields, and costs for peanut seed, data for certified peanut seed were assumed to be rep-

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[9] That A^* in fig. 3 is not an optimum when $\alpha = \beta$ may be rigorously proved by the method of contradiction. If $\alpha = \beta$ and $A = \nu/\mu$, then

$$\frac{dE(C)}{dA} = \frac{\alpha\sqrt{2}}{\mu^3(\sigma^2A^2 + \delta^2)^{3/2}}\,\sigma^2\,\nu\,(\sigma^2\nu^2 + \mu^2\delta^2).$$

Since α, μ, σ, and δ are all positive constants, this first derivative cannot be zero. But this contradicts the assertion that $A = \nu/\mu$ is a critical value. Therefore, A^* does not locate the optimum acreage.

[10] With $\beta < \alpha$ (i.e., underproduction less expensive than overproduction), optimum acreage would shift successively to the left.

[11] The problem of estimating total peanut acreage planted for food purposes need not be dealt with here, since government programs have made planted peanut acres a predetermined variable. If desired, planted acreage could be estimated separately and results applied to this analysis in a stepwise fashion.

[12] In 1972, the total volume of peanut seed was approximately divided among these three types as follows: runners—70%, Spanish—25%, and Virginia—5% (Ethridge, p. 9).

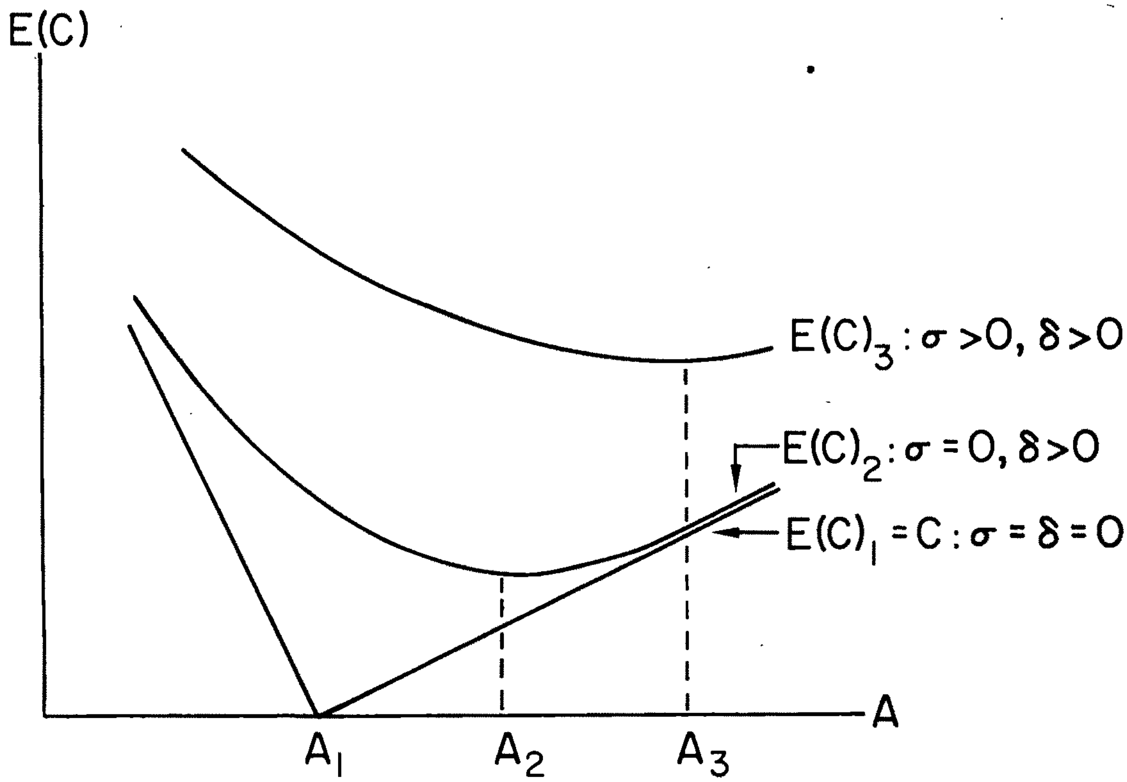

Figure 4. Behavior of $E(C)$ with various degrees of uncertainty, given that $\beta > \alpha$

Table 1. Estimated Values of Exogenous Production, Utilization, and Cost Variables Used in the Model

Variable	Unit of Measure	Type of Peanut			
		All Types[a]	Runner	Spanish	Virginia
Expected seed yield ($\bar{Y}_t$)[b]	lb./acre	1467.10	1529.70	1277.50	1516.50
Expected seed utilization ($\bar{u}_{t+1}$)[c]	lb./acre	156.10	153.90	157.10	185.50
Additional seed growing cost (GR)[d]	$/acre	22.25	22.19	22.27	22.93
Seed processing and storage cost (*PS*)[e]	¢/cwt.	35.00	35.00	35.00	35.00
Expected market price ($\bar{E}_{t+1}$)[f]	¢/lb.	14.40	14.40	14.40	14.40
Yield decrease due to low quality seed (Δ)[g]	%	4.00	4.00	4.00	4.00
Expected peanut yield ($\overline{YP}_{t+1}$)[b]	lb./acre	2454.00	2510.00	2261.00	2637.00
Additional growing cost due to low quality seed (*GC*)[h]	$/acre	10.16	10.02	10.22	12.07
Excess acres planted with low quality seed (θ)[i]	%	50.00	50.00	50.00	50.00
Additional cost for inshipping seed (*CI*)[e]	¢/lb.	3.00	3.00	3.00	3.00
Inshipments of deficit seed (Φ)[i]	%	50.00	50.00	50.00	50.00

[a] Where the data differs among runner, Spanish, and Virginia peanuts, entries in the "all types" column are a weighted average of entries in the other three columns. Weights were determined by the proportion of harvested peanut acreage accounted for by each type in 1972. The weights are: for runners—70.8%, for Spanish—24.6%, and for Virginia—4.6% (Georgia ASCS, p. 146).
[b] Estimated by averaging per acre yields during the years 1970–72. Yield data for peanut seed came from the Georgia Cooperative Extension Service. Yield data for edible peanuts came from USDA (*Crop Production*).
[c] Estimated from the regression equation $\bar{u}_t = -30.28 + 1.58\ R_t$, where R_t denotes the planting rate in pounds per acre. Planting rate data were supplied by the Georgia Cooperative Extension Service. Utilization data came from USDA (*Field Crops*).
[d] Estimated in consultation with seed-processing industry personnel in Georgia. Cost components are the extra cost of registered peanut seed (3 ¢ per pound) and the average per acre premium paid the farmer for growing a seed crop ($15 per acre).
[e] Estimates obtained from industry personnel in Georgia.
[f] Estimated by linear trend regression of average price in Georgia. Price data came from USDA (*Agricultural Prices*).
[g] Estimated in consultation with Georgia Cooperative Extension Service personnel.
[h] Equal to estimated cost of 15% more seed and one additional cultivation. Seed price was estimated by linear trend regression to be 43.4 ¢ per pound. Data on seed prices came from USDA (*Agricultural Prices*) and data on cultivation costs came from Smith and Oliver.
[i] Set at 50% for a base solution. Since they must sum to 100%, Θ and Φ are interdependent.

resentative for all "high quality" peanut seed. This seems a safe assumption, since in 1972–73, about 95% of all peanut seed handled by commercial seed-processing plants was certified (Ethridge, p. 9).

Whether a seed deficit is met by inshipments of high quality seed or by obtaining lower quality seed within the state will vary by areas and firms in the state, as well as according to how widespread the seed shortage happens to be.[13] For simplicity, the proportion of a seed deficit filled by inshipments (Φ) is set at 50%, which implies that the proportion of excess acres planted with lower quality seed Θ is 50%.

After a base solution was obtained, magnitudes of the exogenous variables were systematically changed from those in table 1 so that sensitivity of the optimum solution to their specification could be observed. Some sensitivity results for "all types" of peanuts are reported in a subsequent section of this paper.

Estimation Procedure and Results

The decision variable is acreage to plant for seed in the current year. The objective function to be minimized is expected disequilibrium cost, which is the summation of C_1, C_2, and C_3 as defined in the model section. For any designated level of seed acreage, all elements of these three costs are specified except seed yields and utilization rates. Random errors associated with these two variables receive explicit consideration.

Table 2 summarizes results of regressing seed yields on time and seed utilization rate on planting rate. The standard errors of these regressions were used to define the variances of random numbers generated from the normal distribution, thus generating 300 values of peanut seed yield and utilization rates.[14] Using these data, expected disequilibrium cost associated with various peanut seed acreages could be calculated from equation (11). To do this, an iterative computer procedure was used whereby acreage was incremented 1/10 acre. Cost-minimizing seed acreage was then found by inspection of the computer results.

The unit of analysis in this paper is 1,000 acres of peanuts. Since all cost estimates are assumed to be linearly related to acreage, optimum seed acreage for any number of peanut acres may be easily estimated by scaling these results.

Base solution. The cost-minimizing solution for producing seed is shown in table 3. Using weighted average data for the various peanut types, the optimum seed acreage is 121.4 acres with a minimum expected additional cost of \$693. If utilization uncertainty is (erroneously) ignored, the seed acreage indicated is 114.1 acres—a reduction of 6%. This would result in

[13] In the event of a widespread seed shortage, seed price could become quite inflated, but ramifications of this are not explored here.

[14] Statistics generated by use of these random numbers are constrained to have means and variances that are consistent with the regression error terms; therefore, the simulated data are necessarily consistent with the observed time-series data.

Table 2. Regression Estimation Results for Peanut Seed Yields and Utilization Rates in Georgia, 1963–72

Regressands	Type of Peanut	Regressors[c] Time[d]	Planting Rate[e]	Constant Term	Coefficient of Determination	Standard Error of Regression
Yield[a]	Runner	61.30 (2.79)		855.00	0.49	199.40
	Spanish	28.80 (2.46)		960.80	0.43	106.20
	Virginia	5.42 (4.28)		920.40	0.71	110.50
Utilization[b]	All types[f]		1.96 (5.09)	− 45.60	0.76	11.00

[a] Seed yield (Y_t), in pounds per acre.
[b] Seed utilization rate (u_t), in pounds per acre.
[c] Numbers in parentheses below each coefficient are t-values.
[d] Annual trend variable (1963 = 1, 1964 = 2, . . . , 1972 = 10).
[e] Seeding rate for peanuts (R_t) in pounds per acre.
[f] Seed utilization rate was available only for "all types" of peanut seed. This was regressed on a weighted average of planting rates for the three types of peanuts.

Table 3. Expected Additional Cost to the Agricultural Sector of Growing Seed to Produce 1,000 Acres of Peanuts

Type of Peanut	Uncertainties Considered[a]	Optimum Seed Acreage Indicated	Expected Additional Cost[b]
		(acres)	($)
	P & U	121.4	693
All types	*U*	114.1	757
	None	106.4	1020
	P & U	119.7	738
Runner	*U*	110.2	829
	None	100.6	1231
	P & U	134.0	587
Spanish	*U*	131.1	600
	None	123.0	799
	P & U	133.9	549
Virginia	*U*	129.4	573
	None	122.4	792

[a] P = seed yield uncertainty and U = seed utilization uncertainty.
[b] Cost figures for each seed type are taken from the expected additional cost function which incorporates both production and utilization uncertainties.

an expected disequilibrium cost of $757—an increase of over 8%. If both utilization and yield uncertainties are ignored, the seed acreage indicated is 106.4—a decrease of over 12%. This would result in an expected disequilibrium cost of $1,020—an increase of over 32%.

The fact that optimum acreage successively increases in table 3 as utilization and yield uncertainties are incorporated implies that cost to the agricultural sector for overproduction of peanut seed is less than for underproduction. This may be verified by comparing cost parameters in table 1. The result of increasing acreage is analogous to the case illustrated by figure 4.

Since the means and variances of yield and utilization rates differ by peanut type, optimum seed acreage and minimum expected additional cost also differ (table 3). Runner peanut seed have the lowest average per acre utilization and the highest average per acre yield of the three peanut types. This results in the optimum seed acreage of runners being almost 11% lower than optimum acreages for Spanish and Virginia peanuts. However, runner peanuts also exhibit the largest variations from expected values, which makes minimum expected additional (disequilibrium) cost largest for runners.[15]

Sensitivity analysis. The model was used to evaluate the effect of prices, yields, costs, and inshipment rates on expected disequilibrium cost and optimum seed acreage for the "all types" category. In turn the value of each exogenous variable was varied, while all other exogenous variables were held constant at their respective base-solution values shown in table 1. The impact of each exogenous variable is summarized in table 4.

The specified increases and decreases in the exogenous variables are symmetrical (both 25%), but effects on optimum magnitudes are not. Thus, a 25% increase in peanut price results in an increase of 1.6 acres of seed, but a 25% decrease in peanut price results in a decrease of 1.2 acres of seed. This lack of symmetry in optimum acreage results partly from the changing variance of excess production. However, even with a constant variance the changes in minimum expected additional cost would not be symmetrical because the cost function is not symmetrical. A lower seed acreage has associated with it a higher probability of a deficit which, in this case, is more costly than excess production.

Most factors considered in table 4 have a greater impact on expected additional cost than on optimum seed acreage. For example, increasing the additional growing cost of seed 25% increases minimum expected additional cost 13.5% but decreases optimum seed acreage only 2.1%. Growing costs would be increased on all peanut production grown for seed but sold in the edible market. Thus, the

[15] While both expected total cost and expected disequilibrium cost are affected by the means and variances of yield and utilization variables, effects of the variances are proportionately much greater for expected disequilibrium cost. Expected total cost for growing runner-type peanut seed is no doubt lower than for Spanish and Virginias.

Table 4. Impact of Selected Variables on Peanut Seed Acreage Needed to Minimize Expected Cost of Producing 1,000 Acres of Peanuts

Variable	Change in: Seed Acreage to Minimize Expected Cost	Change in: Minimum Expected Additional Cost
	(acres)	($)
Additional seed-growing cost (GR)		
Increase 25%	−2.6	93.78
Decrease 25%	2.8	−106.04
Seed-processing and storage cost (PS)		
Increase 25%	[a]	12.93
Decrease 25%	0.8	− 13.41
Expected market price ($\bar{E}_{t+1}$)		
Increase 25%	1.6	25.65
Decrease 25%	−1.2	− 29.22
Yield decrease due to low quality seed (Δ)		
Increase 25%	1.6	25.65
Decrease 25%	−1.2	− 29.22
Expected peanut yield ($\overline{YP}_{t+1}$)		
Increase 25%	1.6	25.65
Decrease 25%	−1.2	− 29.22
Additional growing cost due to low quality seed acreage (GC)		
Increase 25%	1.5	23.54
Decrease 25%	−0.5	− 24.84
Additional cost for inshipping seed (CI)		
Increase 25%	1.0	7.20
Decrease 25%	[a]	− 8.18
Inshipments of deficit seed (Φ)		
Increase 25%	−2.5	− 46.28
Decrease 25%	1.7	40.34

[a] Less than 0.1 acre.

expected additional cost curve would be shifted upward and to the right. An increase in the growing cost of seed would increase the additional cost of any excess production. Thus, the optimum seed acreage would decline but the minimum expected additional cost would increase. On the other hand, an increase in the growing cost on acreage planted with low-grade seed would make any deficit in high quality seed more costly. This necessitates an increase of seed acreage in order to reduce the chance of a deficit of seed production.

It is less costly to the state's agricultural sector if a deficit of high quality seed may be met with inshipments rather than using low quality seed. Therefore, increasing the inshipment rate reduces both the optimum seed acreage and minimum expected additional cost. However, an increase in the cost of inshipping seed would result in a higher optimum seed acreage in order to reduce the chance of a deficit in high quality seed (table 4).

Summary and Implications

A methodology has been developed for optimizing planted acreage under yield and utilization uncertainties. Using the concept of disequilibrium costs—added costs incurred solely because actual production does not equal actual utilization—the objective is to determine the planted acreage for which expected value of disequilibrium costs is minimum. A model specifically for peanut seed acreage in Georgia has been formulated and used to estimate optimum seed acreage for planting a fixed peanut acreage. Due to larger costs accruing to the agricultural sector from underproduction of peanut seed, optimum seed

acreage increases substantially when yield and utilization uncertainties are incorporated.

The methodology could be used for diverse commodities, depending on feasibility of estimating relevant costs and distributions of yield and utilization. An important limitation, however, is the lack of consideration of price-quantity interactions; i.e., it is assumed that peanut seed supply and demand are perfectly inelastic with respect to price. This is a tenable abstraction for application made in this analysis; however, in order to be applicable to more general kinds of agricultural production-inventory problems, price variation which accompanies imbalances of supply and demand would have to be explicitly considered.

By redefining the economic subsector for which costs (or perhaps nět returns) are estimated, this methodology could become a tool for market policy analysis. For example, if peanut seed processors and wholesalers were chosen rather than the entire agricultural sector, several of the costs considered in this analysis would become external to the decision process. In particular, costs of underproduction would tend to be ignored because, while the marketing sector has to bear costs associated with overproduction, those associated with underproduction will tend to be borne by producers and consumers. Thus, optimum planted acreage could be substantially less than indicated by this analysis, and the marketing sector would need to hold what it would consider to be excess inventories in order to minimize costs to the agricultural sector. In this case, policies giving the marketing sector incentive to hold these inventories might be desirable.

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External Costs of Land Subsidence in the Houston-Baytown Area

John P. Warren, Lonnie L. Jones, Ronald D. Lacewell, and Wade L. Griffin

Groundwater withdrawal from underground aquifers in excess of natural recharge is causing land surface subsidence along the Texas coast. External costs of subsidence are estimated from a survey of damages and losses in property value in the Houston-Baytown area of Texas. Estimates of total costs, primarily in fresh- and saltwater flooding, are used in a break-even analysis to compare areal costs of groundwater to costs of water from surface sources. Substitution of surface water for all groundwater that results in subsidence is suggested as a means of minimizing total water costs to the area.

Key words: land subsidence, externalities, cost minimization.

The Texas Gulf Coast is affected to an increasing degree by land subsidence, a term applied to compaction of subsurface strata resulting in a lowering of surface elevation. This sinking of the land surface has reached critical proportions in many areas and subsidence of as much as 9 feet has occurred (Gabrysch 1973). The severity of the phenomenon has been aggravated by the proximity of much of the affected area to bay waters. Permanent inundation of property by normal tides and temporary flooding during storm tides have resulted in substantial damages and losses in property values.

The principal cause of land subsidence has been linked to the lowering of artesian pressure heads due to the removal of groundwater (Gabrysch 1973; Gabrysch and Bonnet; Lockwood; Winslow and Doyel). Geologic formations underlying much of this area are composed of unconsolidated deposits of sand and clay. Withdrawal of water decreases the hydraulic pressure that partially supports the overburden. As a result, permanent compaction takes place in the relatively inelastic clays (Gabrysch 1969).

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Engineers generally agree that there is a rate of groundwater withdrawal at which decline of water pressure and thus, subsidence, would be stabilized. Such a maximum acceptable withdrawal rate (*MAWR*) is expected to be equal to the rate of natural recharge of the aquifer, but its actual value for the affected area has not been estimated. The existence of *MAWR* is important, because there is an alternative surface source of water available to help meet area water needs. However, price differentials to the primary user have slowed the substitution of the alternative water supply for groundwater withdrawals.[1]

Previous research on land subsidence emphasized physical characteristics and causes (Gabrysch 1969, 1972, 1973; Gabrysch and Bonnet; Lockwood; Poland and Davis; Winslow and Doyel). The purpose of this analysis is to expand the research to include economic implications by estimating external costs associated with the land subsidence phenomenon in the Houston-Baytown area of the Texas Gulf Coast. Estimates of total costs associated with subsidence are developed from a survey of public and private property within the study area. These cost estimates are used in a break-even analysis to estimate that quantity of water (above some maximum withdrawal rate) at which there is economic

[1] In fact, sufficient unused water is available from surface reservoirs to meet current and projected needs until about the turn of the century. Delivery systems constructed by the Coastal Industrial Water Authority will be completed in 1976.

indifference between ground and surface water, thus establishing an economic criterion upon which total water costs (including those due to subsidence) to the study area may be minimized.

The Cost Minimization Model

Within the affected area, industries and municipalities intensively pump groundwater from a relatively small area of the Chicot and Evangeline aquifers. Pumping costs of the last unit of this resource comprise the marginal private cost to these consumers. However, there is an additional cost resulting from land subsidence. Pumping costs plus subsidence costs of the last unit of resource used comprise the marginal social costs of pumping water. Subsidence costs are the damages and property losses attributable to subsidence in the area and can be considered negative externalities.

The alternative surface source of water has no negative externalities associated with its use, but the direct unit costs are higher than for the common groundwater source.

To minimize costs as a whole, a comparison of costs of the two sources of water is needed. It is assumed in this analysis that all per unit costs are constant at all levels of water use.[2] As mentioned earlier, there exists some *MAWR* at which water pressure and subsidence would be stabilized. Although this rate is not known, its estimation is a physical problem currently under study.[3] Of immediate interest to this analysis is the amount of groundwater withdrawn in excess of *MAWR*. This quantity is called the critical quantity of water Q_c. Associated with Q_c are the external costs of subsidence.

The total cost of pumping water from the aquifer may be expressed as

$$(1) \qquad TC_p = P_p \cdot Q_d + P_s \cdot Q_c,$$

where TC_p = total cost of pumping quantity Q_d, P_p = per unit pumping cost of groundwater, P_s = per unit subsidence-related cost of groundwater, Q_d = total quantity of water pumped, and $Q_c = Q_d - MAWR$, the critical quantity of water or that quantity of groundwater withdrawal associated with surface subsidence.

In equation (1), if the total quantity of water pumped is less than or equal to *MAWR*, TC_p includes only the cost of pumping, $P_p \cdot Q_d$. If the total quantity pumped is greater than *MAWR*, TC_p includes both costs of pumping and costs of land subsidence. Total external (subsidence-related) costs represent the additional costs above pumping costs imposed on the area due to pumping Q_c quantity of water. Hence, total external costs are estimated by $P_s \cdot Q_c$.

The total cost equation with *MAWR* quantity of water pumped and Q_c quantity purchased from the surface source is

$$(2) \qquad TC_a = P_p \cdot (MAWR) + P_a \cdot Q_c,$$

where TC_a = total cost of water used when Q_c is obtained from the surface source and P_a = per unit cost of water from the surface source.

Considering a total-cost curve based on equation (2) for the total quantity of water used, the curve is kinked because quantities above *MAWR* are purchased from the surface source and are more costly per unit.

Since pumping quantities below *MAWR*, i.e., $Q_c = 0$, causes no subsidence, the analysis may be confined to a comparison of the costs of obtaining the critical quantity of water Q_c from the two alternative sources. The least-cost source of this critical quantity of water may be evaluated in terms of the relationship between TC_s, the total cost of pumping Q_c quantity of water, $P_p \cdot Q_c + P_s \cdot Q_c$, and TC_0, the total cost of purchasing Q_c quantity of water from the surface source, $P_a \cdot Q_c$. If $TC_s < TC_0$, continued pumping will be the least-cost alternative for the area. If $TC_s = TC_0$, costs are the same between the two sources. And, if $TC_s > TC_0$, the purchase of Q_c from surface water will be the least-cost alternative for the area.

If *MAWR*, the per unit cost of groundwater, surface water, and subsidence were all known, the least-cost source of Q_c could be readily determined, but *MAWR* and the unit costs of subsidence are unknown. Nevertheless, total subsidence costs can be estimated, and a break-even analysis can be used to solve for a break-even critical quantity of water Q_{be}, where the total cost of water will be equal regardless of source. This break-even critical quantity of water, Q_{be}, may be derived by

[2] This assumption of linearity is probably an oversimplification. Data were insufficient to estimate a continuous functional relationship between subsidence costs and groundwater withdrawals.

[3] The groundwater withdrawal rate at which subsidence would be stabilized is currently under study by geologists and engineers. It is dependent upon the geologic formation underlying the area, the rate of natural recharge, rate of water withdrawals, location of wells, and other factors.

imposing the above equality condition, $TC_s = TC_0$. Then,

$$Q_{be} = \frac{TEC}{P_a - P_p}, \tag{3}$$

where Q_{be} = the equilibrium critical quantity of water where the total cost of Q_c is the same from both sources, and TEC = total external cost of subsidence, calculated as $P_s \cdot Q_c$.

If $MAWR$ were known, the quantity of water use that equates the total costs of the two alternatives, $TC_s = TC_0$, could be found by adding Q_{be} to $MAWR$. Since $MAWR$ is unknown and since TEC is associated with a given level of water use Q_d, an alternative method is to subtract Q_{be} from total water use of the area. This procedure yields an estimate of the magnitude of $MAWR$ that would equate total costs of the two water sources. This magnitude of $MAWR$ is called the break-even withdrawal rate $BEWR$.[4]

Estimating this $BEWR$ is an important first step toward comparing the costs of pumping with the costs of purchasing an amount of water equal to Q_c. For example, if $MAWR$, as estimated by engineers, lies below (above) $BEWR$, then continued pumping of the critical quantity Q_c from underground water would be justified (unjustified) since the total cost from pumping would be less (more) than the total cost from the surface source. If engineers estimate $MAWR$ to be equal to $BEWR$, then from the standpoint of total area costs, there would be indifference as to the source for the critical quantity of water.

Data Collection Procedures

To develop cost estimates associated with subsidence, 300 square miles in the Houston-Baytown area of Texas were plotted on a square mile grid basis and stratified into areas above and below 25-feet elevation.[5] These square mile areas served as a basis for sampling. Industrial areas, containing 19 square miles, and the public sector were subjected to 100% sampling. For all square mile areas identified as residential-commercial and above 25 feet, 10% were selected at random. Within each of these areas, a sample of 5% of the residential and commercial establishments was interviewed. Since it was hypothesized that greater damages would occur at lower elevations, 20% of the square mile areas below 25-feet elevation were selected at random. Ten percent of the residences and commercial establishments within each selected area were interviewed. A total of 441 questionnaires were completed.[6]

Although the study was limited to 300 square miles out of an affected area of over 3,000, random selection of sample areas helped ensure unbiased, systematic enumeration. Any major limitations of the data were probably associated with initial responses, since some respondents may have attributed damages to subsidence that were not a result of that phenomenon. Also, memory failure was high among respondents in reporting events of up to thirty years ago, and there was a high incidence of respondents who only recently moved into the area. To minimize such limitations, dependence was placed on data from the most recent five-year period (1969–73) for the economic analysis of alternative water supplies.[7]

Empirical Results

Physical effects of land subsidence are largely dependent on location. Few structural damages were reported as direct results of subsidence. Most costs and losses associated with subsidence were found to be indirect in nature, caused by either temporary or permanent tidal or freshwater flooding.

As land subsides, more property becomes susceptible to permanent inundation or temporary flooding due to storms or high tides. Often, property is abandoned or frequent inundation renders it virtually useless. Municipalities in the area must often raise the elevations of roads, repair damaged utilities, and construct bridges, dikes, and drainage

[4] The definition of Q_c in equation (1) implies that $BEWR = Q_d - Q_{be}$; $BEWR$ is used in this analysis since it is directly comparable to the physical withdrawal rate, $MAWR$.

[5] The stratification into areas above and below 25-feet elevation was somewhat arbitrary but based on the hypothesis of more extensive loss per square mile at lower elevations. It was learned in the process of the study that proximity to bay waters may have been a better criterion for stratification.

[6] Questionnaires for residential, commercial, and public responses were designed to allow an accounting for year, type, and extent of those damages and losses in property value that property owners attributed directly to subsidence.

[7] By using recent years, memory failure and other limitations were minimized. Also, many of the data were associated with a 6-foot tide which occurred in 1973. Such a tide can be expected to affect the area every 5.13 years (Bodine), so this was a particularly applicable period upon which to base the analysis.

works. Expenditures for protection and repair continually rise within the affected area.

Subsidence resulted in private damages estimated at $60.7 million and private property losses estimated at $48.9 million in the study area between 1943 and 1973. In addition, total public costs were estimated conservatively at over $4 million. Total subsidence-related costs to the area were an estimated $113.6 million during the last thirty years.

During the five-year period from 1969 through 1973, total costs and losses in the area were estimated at nearly $73 million (table 1). Over $70 million of this five-year total resulted from damage and loss in the private sector, while costs of $2.7 million reflected damages in the public sector. Of this total, respondents identified over $53 million in subsidence-related costs and losses that were caused by the 6-foot tide and storm of 1973. These damages and losses were concentrated in areas that had become susceptible to such tidal flooding as a result of subsidence of 6 feet or more. Hence, they were assumed to be attributable to the subsidence phenomenon.

These values provided initial estimates of external costs of subsidence and were used to estimate benchmark or break-even critical quantities of water withdrawal. Average annual costs of subsidence, including both public and private damage and property loss, were estimated at $14.6 million for the area (table 1) and are assumed fully attributable to that quantity of groundwater, Q_c, being withdrawn above the maximum amount that can be withdrawn with no subsequent decline of water pressure.

The economic feasibility of importing surface water in substitution for groundwater may be analyzed by comparing the direct and external (subsidence-related) costs of pumping to the costs associated with purchasing surface water for that quantity of water, Q_c, that exceeds *MAWR*. The average price for surface water was reported to be about 16¢ per 1,000 gallons and for groundwater about 5¢ per 1,000 gallons (Warren et al.). From equation (3), dividing total subsidence-related costs (estimated to be $14,599,893), by the price differential of 11¢ per 1,000 gallons yields an estimate of Q_{be} equal to 132.7 billion gallons a year (BGY). This implies that the purchase of up to 132.7 BGY of surface water would be economically justified.

The magnitude of this estimated quantity of water is most significant. As indicated earlier, *BEWR* corresponding to Q_{be} may be estimated by subtracting Q_{be} from total use, Q_d. However, the recent five-year annual average total water use within the area, as estimated by Gabrysch (1972), is 118.8 billion gallons, a figure well below the 132.7 billion gallons calculated as Q_{be}. Moreover, the highest reported annual withdrawal (126.7 billion gallons in 1972) is 6 billion gallons below Q_{be}. This comparison implies that as long as total water use in the area did not exceed *MAWR* plus the estimated break-even quantity, Q_{be}, of about 133 billion gallons per year, all groundwater withdrawals that result in subsidence should have been replaced by surface water to minimize total water costs to the area.

Further, the estimated annual external costs resulting from subsidence ($14.6 million) were associated with the annual total withdrawal of only 118.8 billion gallons. This implies that even if *MAWR* were zero, the purchase of surface water would have been justified in terms of minimizing total regional water costs.

For example, if all water, Q_d, had been pumped from the groundwater source, total direct costs would have been about $5.9 million. Added to total external costs of about $14.6 million, total costs of pumping Q_d would have been approximately $20.5 million. If *MAWR* were zero and all of Q_d had been purchased from the alternative source, total costs would have been about $18.9 million, representing savings to the area of about $1.6 million. At current prices, the purchase of all

Table 1. Losses Related to Subsidence in the Houston-Baytown Area, 1969–73

Sector	Damages	Property Value Losses	Total
Residential-commercial	$21,294,643	$48,966,137	$70,260,780
Industrial	37,186		37,186
Public	2,701,500		2,701,500
Total	$24,033,329	$48,966,137	$72,999,466
Five-year average	$ 4,806,666	$ 9,793,227	$14,599,893

Source: Warren et al. (p. 56).

of the area's recent water needs above *MAWR* from the surface water source would have been economically justifiable, and even if all water had been purchased, total costs to the area would have been lower. Further, the substitution of surface water for groundwater would have had the effect of totally internalizing to users the negative externalities associated with subsidence.

To investigate the sensitivity of the estimated Q_{be} to relative price differentials, different combinations of pumping and surface water prices were assumed, and equilibrium critical quantities were calculated for each combination (table 2). Each of these equilibrium critical quantities assumes a constant *TEC* of $14.6 million. In all cases, except where pumping costs are set at 5¢ per 1,000 gallons and surface water costs at 20¢ per 1,000 gallons, the equilibrium critical quantity of water exceeds total area use (table 2). Hence, except for this set of ground and surface water costs, this analysis suggests that to permit any subsidence results in failure to minimize total water costs for the area. The results of this study are thus fairly definitive, i.e., if subsidence occurs, groundwater costs, including external costs, exceed the higher direct costs of surface water. Total costs of water for the area are minimized by not permitting groundwater withdrawal beyond the point where subsidence would begin to occur.

Summary and Conclusions

Land surface subsidence in the coastal area of Texas affects over 3,000 square miles. Extensive damage to property due chiefly to tidal and freshwater flooding has resulted. The sinking of the surface has been linked by engineers to the withdrawal of groundwater. Surface water has been introduced into the area, but its substitution for groundwater has been limited because of higher direct costs to users.

For this study, an area of 300 square miles between Houston and Baytown, Texas was identified and a sample of residences, businesses, and public officials was interviewed relative to costs incurred due to land subsidence.

Between 1943 and 1973, costs and property losses in the private sector attributable to subsidence were estimated at $60.7 million and $48.9 million, respectively. Over $4 million in damages were reported in the public sector.

Estimated annual subsidence-related costs and losses of $14.6 million, based on 1969–73 data, were used to evaluate total costs associated with supplying water needs from two alternative sources. A break-even analysis, based on estimated annual subsidence-related costs and current water prices, implies that the purchase of all of the area's recent water needs (up to 133 billion gallons) would have been justified. Therefore, if a rate of pumping at which water pressure declines and surface subsidence would be stabilized could be determined, results of this study strongly suggest that the quantity of current water use above that rate should be purchased from alternative sources, if minimizing total costs to the area is an objective.

This analysis does not consider changes in demand for water, and calculations of *BEWR* must be made individually for any given level of water use. Cost estimates with continued subsidence and changing water demand were not made due to data limitations. However, there are two factors, the lowering of price for the alternative water source and adoption of water recycling by some users, that could contribute to minimizing the effects of increases in the demand for water.

The substitution of surface water for groundwater would result in higher direct costs to users, and initially, some inducement might be needed to encourage consumption of surface water. Defining equitable distribution among users of increased direct costs is a problem not considered in this study, but it will necessarily demand the attention of legal and social planners of the area.

Table 2. Estimated Equilibrium Critical Quantities of Water in the Houston-Baytown Area

Cost of Surface Water (1,000 gals.)	Q_{be}(BGY) $0.05 per 1,000 Gals. Pumped	Q_{be}(BGY) $0.10 per 1,000 Gals. Pumped
$0.10	292.0	
0.15	146.0	292.0
0.16	132.7	243.0
0.20	97.3	146.0

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Groundwater Management and Salinity Control: A Case Study in Northwest Mexico

James W. McFarland

Policy issues associated with the management of a coastal groundwater aquifer and soil salinity are examined for an irrigation area in northwest Mexico. The primary policy issues are the intertemporal rate of use of the groundwater stock, the allocation of water between irrigation and leaching, and the selection of crops. A management model, cast in a dynamic programming format, indicates that the aquifer should be mined at a rapid rate near the beginning of the planning horizon, gradually decline through time, and converge to safe yield after twenty-nine years. Further, a larger percentage of total water use should be allocated to leaching to maintain soil salinity at lower levels.

Key words: groundwater, soil salinity, management, dynamic programming.

The effect of increased levels of soil salinity on the growth of different crops has received considerable attention in the literature (e.g., Bernstein and Richards). Factors which contribute to the buildup in soil salinity have likewise been recognized, and management policies, which relate primarily to the quality of the irrigation water, irrigation practices, and drainage conditions, have been suggested. Most of the work by economists has been in terms of intraseasonal problems associated with the specification and estimation of production relationships, the evaluation of different levels of water quality and the optimal timing and quantity of irrigation water (see Moore, Snyder, and Sun; Yaron; Young, Franklin, and Nobe).

Long-run problems associated with the effect of the accumulation of salts in soils on irrigated agricultural lands have received less attention. Yaron and Olian examine the implications of varying water quality on salt accumulations and leaching water policy in a dynamic model for a perennial crop. More recently, Cummings and McFarland have developed a discrete time control model for the conjunctive management of a groundwater aquifer and soil salinity.

The purpose of this paper, which is in the same vein as these latter studies, is to address selected policy issues encountered in a coastal irrigation area. The next section contains a discussion of the study area and current problems and questions which are of interest. Then a management model which focuses on this set of problems is presented, followed by the empirical results and policy implications.

The Study Area

The Sahuaral irrigation district, located approximately 200 miles south of the Arizona-Mexico border, has been utilized for irrigated agriculture for nearly two decades. Irrigation water in the Sahuaral comes entirely from groundwater sources.

There are several interrelated problems facing the Sahuaral that this study specifically addresses. The first of these relates to the intertemporal rate of use of the groundwater stock, a common property resource.[1] Esti-

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[1] Considerable attention has been given to the optimal manage-

mated storage of water in the aquifer is some 2 billion cubic meters; in recent years, this stock has been mined at a relatively rapid rate. During the past four production periods, 1970–73, the average annual withdrawal was 138 million cubic meters of water with natural recharge estimated at 20 million cubic meters per year. This average annual mining of 118 million cubic meters resulted in the water table falling an average of 1.8 meters per year (Secretaria de Recursos Hidraulicos).

In addition to problems associated with falling water tables which result from high withdrawal rates in excess of recharge, the Sahuaral is experiencing difficulties due to saltwater intrusion.[2] As the groundwater stock is mined and the water level in the aquifer falls, saltwater moves in from the seaward side of the aquifer with saltwater replacing freshwater. The salt content of the water where intrusion occurs is generally too high to be used effectively in agricultural production. In the area where intrusion has occurred, pumps are no longer operated due to the high salinity concentration of the water. In the 1970–73 period, the number of pumps in the region declined from sixty-nine to sixty-four.

Based on data from the Mexican Ministry of Water Resources (Secretaria de Recursos Hidraulicos), the average salinity concentration of the aquifer where intrusion has not occurred is approximately 2 millimhos per centimeter. Using water of this quality for irrigated agricultural production requires special management practices. As water with a high salt concentration is utilized, salts build up in the soil resulting in saline soils. It is possible within limits to control the level of soil salinity. These control measures relate primarily to the application of additional quantities of water to carry the salts out of the root zone (leaching) and to maintain adequate drainage conditions.

Since crops have different tolerances for soil salinity, a decision closely related to the control of soil salinity concerns the selection of the cropping pattern. Determining the cropping pattern which results in the greatest benefits to the region entails an examination of the returns and costs involved with each crop and the relative salt tolerance of each crop.

The principal crops in the Sahuaral in 1972–73 by percentage of total hectares cultivated were: wheat—45%, cotton—29%, sesame—18%, and other (including sorghum and soybeans)—8% (Secretaria de Recursos Hidraulicos). A plan developed by the Secretaria de Recursos Hidraulicos for 1973–74 specifies the introduction of another crop, garbanzo beans, which is grown throughout northwest Mexico. Both cotton and wheat are relatively salt tolerant. Garbanzo beans are more salt sensitive, as are some of the other field crops presently grown in the region.

Given the above discussion of some current problems facing the region, the interrelated issues of concern in this study are as follows. What is the optimal rate of exploitation of the scarce groundwater resource for use in irrigation when consideration is given to present and future benefits and costs, including the impact of saltwater intrusion? Given relatively scarce water supplies and associated high scarcity values for water, to what extent should this scarce resource be used for leaching purposes in order to control soil salinity over time? What are optimal cropping patterns? What is the implication of introducing garbanzo beans on cropping patterns and water use policies?

The Management Model

To give operational form to the problems described above, consider a finite planning horizon of T years ($t = 1, \ldots, T$) where any year t is a production year dichotomized into dormant and growing seasons. The production year is defined so that the dormant season is prior to the growing season.

The groundwater stock at the beginning of year t is denoted by X_t, measured in cubic meters. Water use consists of w_t, water applied for production during the growing seasons, and y_t, leaching water applied during dormant periods.

The groundwater stock changes from year t to $t + 1$ as described by the transition equation

(1) $X_{t+1} = X_t + r_t - (w_t + y_t), X_1 \geq 0.$

The groundwater stock at the beginning of period $t + 1$ equals the stock at the beginning of t, X_t, plus recharge, r_t,[3] less total water use

ment of a groundwater resource over time, including common property aspects of the problem (see, e.g., Burt).

[2] Several previous studies have investigated the effects of saltwater intrusion. Busch, Matlock, and Fogel discuss the problem in the Costa de Hermosillo. Cummings (1971) presents an analysis of the optimal intertemporal rate of exploitation of groundwater stocks with the intrusion of saltwater. Cummings (1974) also gives empirical results from a multistage linear programming model applied in the Costa de Hermosillo.

[3] Sufficient data are not available to estimate a relationship

during t, $w_t + y_t$.[4] The initial groundwater stock is assumed to be known.

A rather simplified approach is taken in the specification of soil salinity in the model. A single state variable, S_t, is used to reflect average soil salinity in a representative hectare under production at the beginning of year t; S represents the level of soil salinity in the top 120 centimeters of the soil profile and is measured in millimhos per centimeter (mmho./cm.). (See Richards for a discussion and definitions relating to saline soils.)

The transition equation for soil salinity follows from a model developed by Bresler for predicting the salt distribution in the soil profile. Bresler's model is based on the law of conservation of mass which states that the amount of salt added to the soil layer minus the amount leached is equal to the net increment (positive or negative) of salt in the soil profile (assuming that the amount of salt absorbed by the crop is negligible):

$$
\begin{aligned}
(2)\ S_{t+1} = {} & [[V_y - 0.5(y_t/A_t - E)]/[V_y \\
& + 0.5(y_t/A_t - E)]]S_t \\
& + c(y_t/A_t)/(V_y + 0.5(y_t/A_t - E)) \\
& + cw_t/(V_w A_t), \\
& \quad \text{for } y_t/A_t - E \leq 2V_y,\ S_1 \geq 0; \\
= {} & c(y_t/A_t)/(y_t/A_t - E) + cw_t/(V_w A_t), \\
& \quad \text{for } y_t/A_t - E > 2V_y.
\end{aligned}
$$

The expression for soil salinity is derived from Bresler's work (p. 228), as was done in the Yaron and Olian paper (see their equations 3, 4, 5, and 6, p. 469).

In equation (2), c is the salt concentration (mmho./cm.) of the water.[5] The moisture content (in meters) of the soil after leaching and irrigation are given by V_y and V_w, respectively, at the time of extraction of salt analyses; E is the soil moisture deficiency up to field capacity when leaching water is applied (in meters), and A_t is the acreage under cultivation measured in square meters.

The level of soil salinity at the beginning of $t + 1$ equals the level at the beginning of t, adjusted by a fraction which indicates the effect of leaching water, plus the salt additions due to leaching and irrigation. Additions of salt attributable to w_t are independent of the level of y_t, given that y_t is applied during the dormant season prior to the growing season during which w_t is applied. In cases where the depth of leaching water does not exceed the soil moisture deficiency, $y_t/A_t \leq E$, no leaching occurs and $y_t/A_t - E$ is set equal to zero. When sufficient leaching water is applied, $y_t/A_t - E > 2V_y$, the concentration of salts in the soil essentially equals the concentration of the leaching water, plus salt additions resulting from w; this is the second expression for S_{t+1}.

To obtain equation (2) from Bresler's paper, a single soil layer is used and his equations are applied twice, making the following assumptions. Water applied for production, w_t, is used only for irrigation. It does not leach salts and w_t is the sum of the intraperiod applications of irrigation water. It is assumed that V_w is constant throughout the growing season. Rainfall is sparse in the region, and it is assumed that it does not have a leaching effect. Leaching water, y_t, is assumed to be applied in single applications prior to the growing seasons.[6]

One problem which arises due to this specification of the transition equation for soil salinity is with respect to acreage. Acreage would be expected to depend on the controls and state variables in the model, in which case an additional state variable for acreage would be required, a requirement which would substantially increase computational complexities (see Burt and Stauber). In this application an

between water use and return flows to the aquifer; however, the estimates of recharge used in the study include an allowance for return flows.

[4] More realistically it might be expected that specific yield of the aquifer would change as the aquifer is dewatered and water table levels fall. It was not possible to obtain adequate data to estimate such a relationship. Thus, based upon Secretaria de Recursos Hidraulicos suggestions, it was assumed that specific yield is a constant 15%.

[5] Generally it is desirable to have water quality, c, dependent upon return flows, making it a variable in the analysis as suggested by Cummings and McFarland. The author was unable to obtain data that would be required to estimate this relation. Limited data that do exist suggest that return flows to the aquifer (the water table for which is some 70 meters below the surface) may be quite small. Therefore, the author opts for a fixed value of c described above.

[6] The author was unable to obtain sufficient data to evaluate alternative technologies for leaching and irrigation. The assumed timing of leaching corresponds closely with current practices in the region. There are also some experimental data which indicate that periodical heavy leaching reduces soil salinity more efficiently than numerous applications with relatively small quantities of leaching water (Yaron, p. 72).

In specifying the salinity equation in this way, it is implicitly assumed that there is adequate drainage. When this is not the case, more numerous applications of leaching water may be more efficient. The results reported here might then overestimate the efficiency of leaching water and underestimate leaching water requirements. This would appear to be a fruitful area for future research.

iterative technique was used to generate values of A_t for use in equation (2).[7]

A dynamic programming format is used in stating the management model and as a solution algorithm. There are 12 discrete values permitted for salinity ($S^j, j = 1, 2, \ldots, 12$); 201 discrete values are permitted for groundwater storage ($X^i, i = 1, 2, \ldots, 201$); w and y are permitted 14 and 5 discrete values, respectively, ($w^k, k = 1, 2, \ldots, 14; y^m, m = 1, 2, \ldots, 5$).[8] To simplify the exposition, superscripts are used on state and control variables only when they are necessary for purposes of clarity. The general recursive relationship is

$$(3)\quad v_n(S, X) = \max \{b(w, y, S, X) - C(y, X) + \beta v_{n-1}[F(w, y, S), X + r - w - y]\};$$

$v_n(S, X)$ may be interpreted as the maximization, with regard to water use at stage n, of immediate net benefits plus the discounted value of net benefits in the remaining $(n - 1)$ stages, given that an optimal policy is followed in the remaining $(n - 1)$ stages. The transition for S from stage n to $n - 1$ is represented by F and is given explicitly by equation (2). Current net benefits corresponding to water use rates w and y given soil salinity and groundwater stocks S and X is given by $b(w, y, S, X) - C(y, X)$. The discount factor is $\beta = 1/(1 + i)$, where i is the discount rate. The number of decision stages remaining in the planning horizon is given by n.

Net benefits, except for dormant period pumping costs, were generated using parametric linear programming. Net farm income was used as a measure of benefits from water use.

The objective function in the linear programming model involved the maximization of net returns from seven annual crops.[9] Yield curves for each crop were estimated as functions of the level of soil salinity. These yield curves, along with prices and production costs, were used to obtain net return per hectare for each crop. Production activities and costs, of course, vary among crops; however, costs such as land preparation, seed, cultivation, fertilizer, insecticides, pumping costs (for w), and harvesting are included. Relative prices and costs were assumed constant throughout the planning horizon. Constraints in the model included restrictions on pumping capacity, land, and total water usage.

The impact of saltwater intrusion is reflected in the model through pumping restrictions imposed on water use. It is assumed that as saltwater intrusion occurs, due to a declining groundwater stock, saltwater simply replaces freshwater in the aquifer and there is no mixing at the interface between salt- and freshwater. Pumping capacity is treated as a function of the groundwater stock.[10]

The groundwater stock enters parametrically in the generation of benefits in two ways. Pumping costs are a function of the stock.[11] As the groundwater stock declines, pumping costs increase. Pumping capacities are a function of the groundwater stock (to reflect the impact of saltwater intrusion); as the stock declines, pumping capacity is reduced.

By parametrically varying the total quantity of irrigation water, the groundwater stock, and the level of soil salinity at the beginning of the growing season, the linear programming solutions yield values of net farm income associated with values of these variables. A cropping pattern is implicit to each point on the benefit function.

Dormant period leaching water enters the benefit function only indirectly through its impact in reducing the relevant level of soil salinity and via the costs associated with this water, $C(y, X)$. The cost function on leaching water is influenced by the level of the groundwater stock in the same way as pumping costs for irrigation water are affected.

Thus, the linear programming model is run for combinations of w and y with selected

[7] Initial values for the time path of A were chosen, and the model was run. The values of the A's corresponding to this solution were then used in the program. This iterative procedure was continued until the acreages used in the model approximated the acreages implied by water use in the optimal solution.

[8] The values for X range from 0 to 2 billion in increments of 10 million; the values for S range from 2 to 24 in increments of 2; the values for w range from 0 to 130 million in increments of 10 million; and the values of y range from 0 to 40 million in increments of 10 million.

[9] The crops included in the analysis are cotton, wheat, sesame, safflower, soybeans, sorghum, and garbanzo beans. It would have been desirable to include other salt-tolerant crops, such as barley. Data relevant for such crops as they might be produced in the study area do not exist.

[10] Sufficient data for the study area does not exist to estimate the relationship between the rate of intrusion and the groundwater stock. It was necessary, therefore, to use an assumed rate of intrusion as the stock declined. The same rate as that used by Cummings (1974) for the nearby Costa de Hermosillo was assumed in this study. Using this rate and the distribution of pumps in the region, a relationship between the groundwater stock and pumping capacity was estimated.

[11] Admittedly, pumping costs in the model are represented in a somewhat simplified fashion in that they represent an average cost, with the groundwater stock used as a surrogate for depths. Of course, this treatment abstracts from a number of issues related to optimal investment strategies, a topic which lies beyond the scope of this paper. A conceptual framework for this more general problem is given in Cummings and McFarland.

combinations of X and S. Using these solutions with interpolations, a matrix of values for the benefit function is generated.[12] Values from this matrix are utilized in the dynamic programming analogue for the values of $b(w, y, S, X)$.

The decision variables in the dynamic programming model are restricted to satisfy the following conditions at each stage:

$$w + y \leq X + r, \tag{4}$$

$$y \leq DPC(X), \tag{5}$$

and

$$0 \leq w, y. \tag{6}$$

Equation (4) constrains total water use at each stage, $w + y$, so that it does not exceed the groundwater stock plus recharge, $X + r$. Dormant period leaching water applications, y, are restricted through an upper bound on dormant season pumping capacity, $DPC(X)$, by equation (5). Pumping capacity restrictions for w are imposed within the linear programming model. Both controls are restricted to be nonnegative numbers, equation (6).

Solution of the dynamic programming formulation yields optimal use rates for irrigation water and leaching water throughout the T-year decision-making horizon. The levels of the groundwater stock and soil salinity are also determined through time. Given the determination of the values of the controls for given states, cropping patterns are implied by the benefit function, and they can be obtained from the linear programming results.

Insights into the decision regarding water use policies can be gained by examining the marginal net benefits associated with irrigation water and dormant leaching water, MBW and MBY respectively, and the marginal user costs of this water in terms of the impact on the groundwater stock and soil salinity, UCW and UCY respectively. The user cost associated with w is the present value of the sum of marginal returns which are foregone in all future periods as a result of using an additional unit of w at present. This cost reflects both the effect of incrementally reducing the groundwater stock and increasing the level of soil salinity. Similarly, with regard to y, the user cost measures the marginal impact that an additional unit of y has on the groundwater stock and soil salinity. Irrigation water use in each period is pushed to the point where MBW = UCW.[13]

Over time, the marginal net benefits for w shift downward as the groundwater stock declines and pumping costs rise. Also, the user costs associated with w shift upward as the groundwater stock becomes more scarce and the impacts of seawater intrusion become more costly.

The analogous conditions for y would be to increase the use of y up to the point where the marginal net benefits for y are equated with the marginal user costs for y plus the marginal value of pumping capacity.

Empirical Results and Policy Ramifications

The management model was solved using a discount rate of 10%,[14] a value for water quality of 2.0 mmho./cm.[15] and a constant value for recharge of 20 million cubic meters. The model was solved for a fifty-year planning horizon. Using initial states $X = 2$ billion cubic meters and $S = 8$ mmho./cm.,[16] table 1 shows the time paths for the groundwater stock, total water use, irrigation water, and leaching water. For stage 50 (year 1), the optimal solution calls for total water use of 150 million cubic meters with $w_1 = 110$ million cubic meters and $y_1 = 40$ million cubic meters.[17]

[12] Given the large number of combinations which are required for a complete enumeration of all possible runs, for purposes of practicality, eleven values of X, equally spaced between 0 and 2 billion, were used. The intermittent values of b were then approximated using linear interpolation. After initial runs, it was determined that for values of S (adjusted for leaching) above 12 mmho./cm., the benefit function is zero. Although several of the crops considered have positive yields beyond 12 mmho./cm., none of these crops were profitable when the level of soil salinity exceeded 12 mmho./cm. The variable y does not directly enter the linear programming model. This yields 11 (for X) × 6 (for S, adjusted for leaching) × 14 (for w) computer runs.

[13] For an examination of decision rules with regard to the general problem concerning optimal rates of use of resources, see Burt and Cummings. Decision rules for a model that encompasses the one presented here are discussed in Cummings and McFarland.

[14] This choice of the discount rate was made based upon the fact that this is the rate that is commonly used in the Secretaria de Recursos Hidraulicos planning process. The discount rate controversy, although interesting, is beyond the scope of this paper. A sensitivity analysis of discount rates did not materially alter the conclusions presented.

[15] Given, as suggested above, that recharge estimates include return flows, the use of a constant for natural recharge overestimates natural recharge in later years given that water use declines in time.

[16] These initial values for states approximate current conditions.

[17] In year 1 (stage 50), the approximate marginal net benefits for a value of w of 110 million cubic meters is 0.136 pesos. The marginal user cost corresponding to this value of w is approximately 0.134 pesos. Irrigation water w is applied at 110 million cubic meters since MBW is approximately equal to UCW at this

Table 1. Time Paths for Groundwater Stock, Total Water Use, Irrigation Water and Leaching Water

Year	X (10^6m^3)	$w+y$ (10^6m^3)	w (10^6m^3)	y (10^6m^3)
1	2000	150	110	40
2	1870	150	110	40
3	1740	140	100	40
4	1620	140	100	40
5	1500	140	100	40
6	1380	140	100	40
7	1260	120	90	30
8	1160	120	90	30
9	1060	110	80	30
10	970	110	80	30
11	880	110	80	30
12	790	100	70	30
13	710	80	60	20
14	650	80	60	20
15	590	80	60	20
16	530	80	60	20
17	470	70	50	20
18	420	70	50	20
19	370	70	50	20
20	320	70	50	20
21	270	40	30	10
22	250	40	30	10
23	230	40	30	10
24	210	40	30	10
25	190	40	30	10
26	170	40	30	10
27	150	30	20	10
28	140	30	20	10
29	130	20	10	10
30	130	20	10	10

As shown in table 1, the groundwater stock is mined at a rapid rate near the beginning of the planning horizon, gradually declines in time, and converges to recharge after twenty-eight years. Dormant leaching water applications y are maintained at approximately a constant percentage (33% to 43%) of irrigation water w until total water use begins to converge to steady state conditions, after which leaching water increases slightly as a percentage of irrigation.[18] The optimal policies for irrigation water and leaching water are such that soil salinity at the beginning of the growing season is maintained below 6 mmho./cm. over the entire decision horizon.

Digressing for a moment, an examination of the linear programming results suggests that for levels of soil salinity of 2 mmho./cm., the primary crops would be garbanzo beans, sesame, and cotton. Linear programming results, where higher salt concentrations are imposed, result in similar cropping patterns; however, there is a shift to a lower percentage of land used for garbanzo beans, which is a relatively salt sensitive crop. When soil salinity reaches 8 mmho./cm., the cropping pattern changes to cotton and wheat. At higher levels of salinity, cotton is the predominant crop. Beyond 12 mmho./cm., none of the crops are profitable.

Combining the results from the management model with the linear programming solutions suggests substantial changes from current crop patterns. Specially, the crop pattern indicated by this analysis for year 1 (stage 50) is: garbanzo beans—58%, sesame—31%, and cotton—11%. These results support proposals by the Mexican government (Secretaria de Recursos Hidraulicos) for the introduction of the garbanzo bean and a reduction in the large acreages which are allocated to wheat. This change in the cropping pattern is indicated since the level of soil salinity at the beginning of all growing seasons is maintained below 6 mmho./cm. throughout the planning horizon, in contrast to current practices where larger salinity levels are being maintained. The results of this study also suggest that a higher proportion of total water use should be allocated for leaching purposes than is the case under current practices. Currently about 15% of water use is for leaching.

Focusing now on groundwater storage, as the groundwater stock is being mined to the point where use is at safe yield in year 29, a number of changes of consequence take place. First, saltwater intrusion is increased by 8 kilometers. Second, the number of pumps falls from 64 to 15, and monthly pumping capacity declines to 4.4 million cubic meters.[19] These changes reduce the feasible irrigable area to 2500 hectares.

If current operating conditions continue, a situation similar to that described above would be expected sooner. The Mexican government is extremely concerned with such a possibility, not only in the Sahuaral district but in the nearby Costa de Hermosillo irrigation district. The government's response to these conditions of growing water scarcity has

point; beyond 110 million cubic meters (with the discrete approximation), UCW > MBW. In year 28, the marginal net benefits for a value of w of 20 million cubic meters is 0.618 pesos with an associated user cost of 0.615 pesos. Again the decision is made at the margin with water use for irrigation pushed to the point where MBW approximately equals UCW.

[18] This results from the discrete nature with which the controls are specified; thus, beyond this point, the solution algorithm overestimates leaching water applications.

[19] This value for pumping capacity is derived from the relationship between pumping capacity and the groundwater stock.

been the proposal of a major interbasin water transfer, details of which are reported by Cummings (1974).

Conclusions

The results suggested in this work imply a pattern of water use in the Sahuaral irrigation district which may postpone to some extent the immediate need for alternative water sources, particularly such costly water sources as the proposed interbasin water transfer. This is particularly relevant given the possibility of developing alternative water supply systems to alleviate the problem suggested by Cummings (1974).

Several aspects of the problem studied here remain for further analysis and refinement. A wide range of investment decisions have not been considered. Structures which might increase irrigation and leaching efficiency (artificial drains) or investments to slow the rate of saltwater intrusion (injection wells, relocation of pumps) have not been evaluated. In addition, alternative technologies for irrigation and leaching, varying land types and quality, different and more salt-tolerant varieties of crops, stochastic elements of the system, and varying water quality are not reflected in the results.

To incorporate the multitude of factors associated with this problem into a framework for analysis is a formidable task. The dynamic programming framework is readily adaptable to nonlinear multistage decision problems, both deterministic and stochastic. A major drawback of this approach, however, arises due to the well-known problem of "dimensionality" (see Bellman; Burt and Stauber). If this approach is to be used to gain insights into an extended version of the problem taking into account many of the above-mentioned factors, it would appear that a partial analysis for subsets of the system combined with sensitivity analysis might be informative. An alternative approach, such as that suggested by Yaron (see also Young, Franklin, and Nobe), combines simulation techniques with optimization models. A major concern, however, regardless of the method employed, is the availability of sufficient data to use in the assessment of alternative management policies in a particular irrigation area.

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An Economic Evaluation of Nitrogen Fertilization of Grasses When Carry-over is Significant

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An economic model is developed to determine optimal nitrogen fertilization policies for seeded grasses in semiarid regions where nitrogen carry-over is significant. The problem is cast in the framework of stochastic dynamic programming and an application of the model is made at two sites in the Nothern Great Plains. A new statistical method was used to estimate carry-over nitrogen and the forage yield-response function simultaneously. Nitrogen carry-over was estimated implicitly through yield response without direct measurements of nitrogen.

Key words: range fertilization, nitrogen carry-over, fertilizer economics, dynamic programming.

There is considerable evidence that grasses growing in semiarid regions generally respond to nitrogen fertilizer and that nitrogen carry-over from year to year can be an important source of nitrogen in subsequent growing seasons (Black; Power 1967, 1968; Thomas and Osenbrug). Determination of optimal fertilization policies is considerably complicated by nitrogen carry-over. The decision problem is dynamic and is further complicated if carry-over is stochastic. Stochastic carry-over is quite plausible when the relationships between seasonal precipitation, forage yield, and nitrogen recovery by the grass crop are considered (Stauber and Burt). The determination of optimal fertilization policies for dryland grasses must be cast in a dynamic stochastic framework.

The Decision Model

Economic analysis of nitrogen fertilization when carry-over is significant and stochastic involves a determination of the sequence of decisions regarding the application of nitrogen fertilizer which will maximize expected present value of net returns. The basic approach is to find a decision rule which specifies the amount of nitrogen to apply in a particular year, given the amount of plant-available nitrogen carried over from previous years. Formally, the decision rule is a functional relationship between the amount of fertilizer applied and the estimated amount of plant-available nitrogen in the soil at the appropriate time for application of fertilizer.

The problem can be viewed as that of maintaining an optimal inventory of plant-available nitrogen in the soil under conditions of stochastic demand arising from random precipitation. Economic considerations must include costs other than the purchase cost of fertilizer. An important trade-off exists between interest and spreading costs; infrequent applications in large amounts save spreading costs but increase interest costs through a larger average investment. Then on the revenue side is the usual consideration of crop response to total plant-available nitrogen, the sum of carry-over nitrogen and that applied currently as fertilizer.

An expected value criterion applied to discounted net returns over a long planning horizon automatically weighs all of these economic trade-offs simultaneously. A practical method for obtaining solutions to such problems is stochastic dynamic programming applied to a Markov chain approximation of the continuous variable problem (Bellman and Dreyfus, p. 297).

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Seasonality of production in agriculture makes an annual period for decision purposes a particularly convenient choice, and in the case of dryland grasses, there would appear to be little advantage in allowing a more frequent choice of fertilizer application. Only a single state variable is used to describe the decision process, namely, a measure of available nitrogen in the soil at the beginning of the season. If the data base had been sufficient, soil moisture used as a second state variable would have exploited more information. The single decision variable is nitrogen fertilizer applied at the beginning of the season.

Excluding soil moisture as a state variable does not create any specification errors in the Markov chain model as might be expected. The first-order dependence structure of the Markov chain can still be accomplished by implicitly using an unconditional probability distribution for soil moisture and deleting soil moisture as a state variable. Nevertheless, useful decision information is ignored in the model and a lower expected value of the criterion function is obtained in the optimization model as compared to using soil moisture as a second state variable.

The usual convention of dynamic programming is followed in which stages are counted from the end of the planning horizon instead of the beginning. The following notation and definitions are made with the stage of the process denoted by subscripts and the index n implying a particular stage, $n = 0, 1, \ldots, N$. All variables are on a per-acre basis: R_n = residual nitrogen in the soil in stage n, a measure in pounds of nitrogen carried over from applications in previous years (the state variable); A_n = pounds of nitrogen applied to the crop in stage n (the decision variable); W_n = seasonal precipitation in inches received during the growing season in stage n: $c(A_n)$ = costs associated with the decision to apply A_n pounds of nitrogen (a discontinuous function at $A_n = 0$, to account for a fixed spreading cost per acre); $h(A_n + R_n)$ = gross value of the forage produced in stage n with harvest costs deducted; $q(A_n,R_n) = h(A_n + R_n) - c(A_n)$, the expected immediate net returns associated with the decision to apply A_n pounds of nitrogen, given that the level of residual nitrogen is R_n; $f_n(R_n)$ = discounted expected net returns from an n-stage process under an optimal policy when the initial state is that defined by R_n (the criterion is maximum expected value of discounted net returns), $n = 1, 2, \ldots, N$; and $f_0(R_0) = 0$, that is, the residual nitrogen in the soil at the end of the decision process has no market value.

The transformation function for the state variable R_n, given by

$$R_{n-1} = \Phi(A_n, R_n, W_n), \tag{1}$$

simply states that residual nitrogen in stage $n - 1$ is some function of applied nitrogen, carry-over nitrogen, and seasonal precipitation in the immediately preceding period.

The dynamic programming formulation complete with the recurrence equation can now be presented as

$$\begin{aligned} f_1(R) &= \max_A q(A,R), \\ f_2(R) &= \max_A [q(A,R) + \beta E f_1(\Phi(A,R,W))], \\ &\vdots \\ f_n(R) &= \max_A [q(A,R) + \beta E f_{n-1}(\Phi(A,R,W))]. \end{aligned} \tag{2}$$

Subscripts denoting the stage have been deleted from the state variable R and decision variable A to simplify the recurrence equation; each of these variables is associated with stage n in the last expression of equation (2). The symbol E denotes the expectation operator on the random variable W which is precipitation, while β denotes the appropriate discount factor, i.e., $\beta = 1/(1+r)$, where r is the interest rate. Solution methods for equation (2) are given in Burt and Allison. Basically, the procedure is to solve for the entire equation, $f_1(R)$, by numerical methods, then solve for $f_2(R)$, and so on until $f_n(R)$ is obtained with n large enough to encompass the longest planning horizon of interest.

Application to Fertilization of Seeded Grasses in the Northern Great Plains

This dynamic programming model is used to analyze the economics of nitrogen fertilization of seeded grasses at Newell, South Dakota and Moccasin, Montana.

Physical Relationships

Before economic analysis can proceed, the yield-response relationship and the nitrogen carry-over function must be quantified. If the

second relationship can be determined, the problems in estimating the first are no different than those faced in quantifying any crop response to fertilizer. Estimation of a nitrogen carry-over function is complicated by the difficulties of measuring carry-over nitrogen in the soil. Tracing the destination of fertilizer nitrogen in perennial grasses has been a difficult task for researchers (Power 1967).

To circumvent actual measurement of carry-over nitrogen, the carry-over function is estimated implicitly through yield response (Stauber and Burt). The grass yield equation uses nitrogen as an explanatory variable, a variable comprised of two components, currently applied nitrogen and carry-over nitrogen. The measure of nitrogen has its origin at the level of plant-available nitrogen present in the soil before nitrogen was applied. A first-order difference equation is postulated to describe nitrogen carry-over. The difference equation is fitted to the data simultaneously with the yield equation and does not require measurements on residual nitrogen. The crux of the method is to specify a comprehensive, logically consistent model of both yield response and nitrogen carry-over such that the only observed measurements required are applied nitrogen and grass yield.

Data used in the analysis were obtained from two experiments designed to evaluate the effects of nitrogen fertilizers and seasonal precipitation on the yield and composition of seeded grasses. The experiments were also designed to evaluate carry-over nitrogen effects on forage yield. One experiment was conducted at Newell, South Dakota from 1952 to 1957 on bromegrass-crested wheatgrass (Thomas and Osenbrug), and the other experiment was conducted at Moccasin, Montana from 1964 to 1967 on crested wheatgrass.

Plant-available nitrogen and weather conditions were hypothesized to be the important factors influencing forage yields. Specifically, it was assumed that

$$(3) \qquad Y_t = f(N_t, W_t),$$

where Y_t = hay yield in pounds per acre for year t, and $N_t = A_t + R_t$ = plant-available nitrogen in pounds per acre in year t, while A_t, R_t, and W_t are as defined earlier for the dynamic programming model except chronological time t replaces the stage n of the decision process.

Some measure of plant-available soil moisture should have been included in W_t, but such data were not available. The carry-over relationship is specified by the first-order difference equation

$$(4) \quad R_t = \alpha_0(A_{t-1} + R_{t-1})^{\alpha_1} W_{t-1}^{\alpha_2}, \qquad t = 1, 2, \ldots,$$

where α_i = an unknown parameter in the carry-over equation, $i = 0, 1, 2$.

The yield relationship of equation (1) is approximated by the polynomial

$$(5) \quad Y_t = \beta_0 + \beta_1 N_t + \beta_2 W_t + \beta_3 N_t^2 + \beta_4 W_t^2 + \beta_5 N_t W_t + \beta_6 N_t^2 W_t + \beta_7 N_t W_t^2 + \epsilon_t,$$

where N_t and W_t are defined as above, ϵ_t = random error term to which the standard assumptions of the general linear model of statistics apply, and β_i = unknown parameter reflecting the net effect of the ith term of the polynomial, $i = 0, 1, 2, \ldots, 7$.

Available nitrogen in year t is a function of nitrogen applied in year t and applied nitrogen and growing season precipitation in preceding years. Consequently, forage yield in year t is dependent upon applied nitrogen and precipitation in preceding years. Since

$$(6) \qquad N_t = A_t + R_t,$$

it is seen from equation (5) that forage yield is a function of A_t, R_t, and W_t. Iteratively substituting back into the difference equation in R_t, as given in equation (4), would permit getting R_t as a function of $A_1, A_2, \ldots, A_t$, but the nature of equation (4) does not let us get a simple expression for such a solution even though it clearly exists conceptually. This implicit solution for R_t in the variables $A_1, A_2, \ldots, A_t$ together with equation (6) makes forage yield expressed by equation (5) implicitly a function of $A_1, A_2, \ldots, A_t, W_1, W_2, \ldots, W_t$, and expected yield is a function of only $A_1, A_2, \ldots, A_t$. The nonlinearities in equations (4) and (5) make forage yield nonlinear in the parameters $\alpha_0, \alpha_1, \alpha_2, \beta_0, \beta_1, \ldots, \beta_7$ as well as nonlinear in the variables.

Statistical estimates of the forage yield parameters were obtained by nonlinear least squares applied to equation (5), recognizing that equations (4) and (6) provide additional relationships which make forage yield of the form

$$(7) \quad Y_t = g(A_1, A_2, \ldots, A_t, W_1, W_2, \ldots, W_t; \alpha_0, \alpha_1, \alpha_2, \beta_0, \beta_1, \ldots, \beta_7).$$

Nonlinear least-squares algorithms solve a sequence of linear regressions (or modifications of them) where residuals from a temporary parameter vector serve as the dependent variable; partial derivatives of the regression function with respect to parameters serve as the matrix of independent variables, where the partial derivatives are evaluated at the temporary value of the parameter vector (Draper and Smith; Marquardt 1963). For given values of the parameters, Y_t in equation (5) can be calculated numerically in a recursion formula by using equations (4) and (6), which permits computation of the needed residuals at a given iteration of the nonlinear least-squares algorithm. The partial derivatives of Y_t with respect to the parameters are also calculated in recursion formulas by repeated applications of the chain rule of the calculus for a hierarchy of functions of functions. The procedure used in this study was an algorithm developed by Marquardt (1963, 1966). A simplified explanation of Marquardt's algorithm is given by Conway. An excellent reference on nonlinear estimation in general, including Marquardt's method, is chapter 7 in Draper and Smith.

Since both sets of parameters, the $\{\alpha_t\}$ and $\{\beta_t\}$, are estimated simultaneously, the carry-over equation is estimated in the process of estimating the yield equation. Statistical estimates for data from the two locations are summarized in table 1. Latin letters are used to denote sample estimates of corresponding parameters.

There is a great deal of similarity between the estimated parameters of the model at the two locations. The signs of the estimates are in complete agreement between the two locations. Also, the fit of the model as indicated by the coefficients of determination are nearly the same. Although the estimates for b_3 are positive, those for b_6 are negative and dominate b_3 over sample values of the precipitation variable, W_t, resulting in a negative net effect for the nitrogen-squared terms. The estimates of the intercept, b_0, are of little interest since the origin is far removed from the sample values of the independent variables. The relatively weak statistical relations associated with terms involving W_t^2 are not unexpected since only six and four separate values (years of data) of the precipitation variable were generated by the experiments at Newell and Moccasin, respectively. Considered jointly, the values of other parameter estimates in the yield equations are plausible since the yield response surfaces exhibit positive and diminishing marginal yield with respect to each nitrogen and precipitation over the region of sample data.

The second-order mixed derivative,

$$\frac{\partial^2 Y_t}{\partial W_t \partial N_t} = b_5 + 2b_6 N_t + 2b_7 W_t, \tag{8}$$

Table 1. Regression Results for Yield and Carry-over Equations

		Newell		Moccasin	
Coefficient	Associated Variable	Estimate	Standard Error[a]	Estimate	Standard Error[a]
Carry-over equation:					
a_0	—	3.9209	1.9895	24.1314	15.4570
a_1	N_t	1.0405	0.08343	1.2459	0.0963
a_2	W_t	−1.1566	0.2814	−2.4772	0.2510
Yield equation:					
b_0	—	−476.25	306.91	−2686.78	518.75
b_1	N_t	−5.5042	3.2328	−55.9122	12.1362
b_2	W_t	245.049	105.988	690.083	117.542
b_3	N_t^2	0.00433	0.00969	0.12163	0.0447
b_4	W_t^2	−9.9584	8.4730	−31.5807	6.3305
b_5	N_tW_t	2.4524	0.8479	12.0409	2.5212
b_6	$N_t^2W_t$	−0.00336	0.00147	−0.02009	0.00445
b_7	$N_tW_t^2$	−0.03314	0.06575	−0.32549	0.1324
Standard error of the estimate:			197.86	280.24	
Coefficient of determination:			0.923	0.928	

[a] The standard errors are only approximate as a result of nonlinearities in the parameters of the fitted equation. Since the parameter set $\{\alpha_t\}$ is the source of nonlinearity, the classical theory of linear regression applies conditionally given the $\{\alpha_t\}$ i.e., if we take the $\{\alpha_t\}$ as given at estimated values then the standard errors are exact and have their usual interpretation. It also follows that any significance tests are either only approximate or hold only conditionally with the $\{\alpha_t\}$ at their estimated values.

portrays the nature of interaction between nitrogen and precipitation. The interaction is positive over the sample region for nitrogen and precipitation at both Newell and Moccasin, but it diminishes with respect to the level of either variable since b_6 and b_7 are negative.

It is useful to examine the expectation of the yield and carry-over functions taken with respect to precipitation, i.e., the random variable W_t. The derived relationships for the carry-over functions are

(9) $E(R_t|N_t) = 0.5069\, N_{t-1}^{1.0405}$

and

(10) $E(R_t|N_t) = 0.1615\, N_{t-1}^{1.2459}$

for Newell and Moccasin, respectively. The amount of carry-over nitrogen and the carry-over proportion are depicted in table 2.

The derived relationships for the yield functions are

(11) $E(Y_t|N_t) = \underset{(73.3)}{659.7} + \underset{(1.267)}{9.722N_t} - \underset{(0.004)}{0.0192N_t^2}$

and

(12) $E(Y_t|N_t) = \underset{(39.4)}{730.0} + \underset{(1.546)}{20.107N_t} - \underset{(0.012)}{0.0447N_t^2}$

for Newell and Moccasin, respectively. The parenthetical numbers are standard errors of the respective coefficients above. The estimated relationships between nitrogen and forage yields are depicted in table 3. In addition, the standard errors of the estimated yield values are given.

The Empirical Decision Model

With the necessary physical relationships specified, the decision model can be formulated. The procedures were identical at both locations, but the empirical information from Newell will be used for purposes of illustration. Numerical solution of the decision model requires the decision variable A_n and the state variable R_n to be approximated by discrete intervals on their continuous scales of measurement. These intervals on R and A are denoted by $i = 1, 2, \ldots, M$ and $k = 1, 2, \ldots, K$, respectively. The K levels of A (pounds of nitrogen applied per acre) were $0, 5, 10, \ldots, 250$. The M intervals of R (pounds of residual nitrogen per acre present in the soil in the spring) were 0 to 4.99, 5 to 9.99, 10 to 14.99, . . . , 245 to 249.99. Each of these intervals was represented by its approximate midpoint value, 2.5, 7.5, 12.5, . . . , 247.5.

The expected immediate returns function $q(A,R)$ for Newell is given by

(13) $P_F\,(659.7 + 9.72N_t - 0.0192N_t^2) - P_N A_t - AC,$

where P_F = gross value of forage per pound with harvest costs deducted, P_N = cost of nitrogen per pound, an AC = per-acre cost of applying nitrogen. The expression involving N_t is the expected yield equation (11) for Newell.

Table 2. Estimated Nitrogen Carry-over and Carry-over Proportion under Expected Precipitation Levels

	Newell		Moccasin	
Available Nitrogen	Nitrogen Carry-over	Carry-over Proportion	Nitrogen Carry-over	Carry-over Proportion
(lb./acre)	(lb./acre)		(lb./acre)	
20	11.4	0.572	6.7	0.337
40	23.5	0.589	16.0	0.400
60	35.9	0.598	26.5	0.442
80	48.4	0.605	37.9	0.474
100	61.1	0.611	50.1	0.501
120	73.8	0.615	62.9	0.524
140	86.7	0.619	76.2	0.544
160	99.6	0.623	90.0	0.562
180	112.6	0.626	104.2	0.579
200	125.6	0.628	118.9	0.594
220	138.7	0.631	133.8	0.608
240	151.9	0.633	149.2	0.622

Table 3. Estimated Forage Yields under Expected Precipitation Levels

Plant-Available Nitrogen	Newell Forage Yield	Newell Standard Error[a]	Moccasin Forage Yield	Moccasin Standard Error[a]
(lb./acre)	(lb./acre)	(lb./acre)	(lb./acre)	(lb./acre)
0	660	73	730	39
20	846	59	1113	35
40	1018	52	1462	41
60	1174	51	1774	45
80	1315	54	2051	47
100	1440	59	2292	48
120	1550	64	2498	57
140	1645	67	2667	81
160	1725	69	2801	119
180	1789	70	2899	170
200	1837	70	2961	231
220	1871	71	2988	303
240	1889	73	2978	384
260	1892	78	—	—

[a] The standard error is for mean yield taken with respect to both seasonal precipitation (W_t) as well as experimental error (ϵ_t) and therefore, reflects sample variation in only the three parameter estimates of equations (11) and (12).

The other empirical information needed for numerical solution of the model is a specification of the stochastic nature of the process, explicitly, the probability distribution of residual nitrogen R. In the discrete formulation of the model, the probability distribution for R can be summarized by the finite set of conditional probabilities, referred to as transition probabilities: p_{ij}^k = the probability that the process will occupy the jth state in stage $(n-1)$ given that it occupies the ith state in stage n and the kth decision is made. The transition probabilities are obtained by utilizing a general form of the transformation function given in equation (4) where time is measured by the dynamic programming stage n instead of by time t, that is,

$$(14) \qquad R_{n-1} = \alpha_0(A_n + R_n)^{\alpha_1} W_n^{\alpha_2}.$$

The probabilities sought are given by

$$(15) \qquad Pr\,[R_{n-1} = r_j | R_n = r_i, A_n = a_k],$$

where $r_j \doteq j$th level of residual nitrogen, r_i = ith level of residual nitrogen, and a_k = kth level of nitrogen application. For R_{n-1} to be considered to be equal to r_j, the value of R_{n-1} must fall into the interval which has r_j as a midpoint, that is, $r_j^* < R_{n-1} \leq r_j^{**}$, where r_j^* and r_j^{**} are the lower and upper limits respectively of the interval described by the midpoint value r_j.

Then the desired probability

$$p_{ij}^k = Pr\,[R_{n-1} = r_j | R_n = r_i, A_n = a_k]$$

is given by

$$(16) \qquad p_{ij}^k = P_r[r_j^* < \alpha_0(A_n + R_n)^{\alpha_1} W^{\alpha_2} \leq r_j^{**}],$$

or

$$p_{ij}^k = Pr\left[\frac{r_j^*}{\alpha_0(A_n + R_n)^{\alpha_1}} < W_n^{\alpha_2} \leq \frac{r_j^{**}}{a_0(A_n + R_n)^{\alpha_1}}\right],$$

which can be evaluated by computing $W_n^{\alpha_2}$ from existing precipitation series and making relative frequency counts for given r_j^*, r_j^{**}, A_n, and R_n. Note that α_0, α_1, and α_2 are replaced by known numbers from table 1, i.e., their least-squares estimates.

The dynamic programming recursion formula, equation (2), for this application is

$$(17) \qquad f_n(i) = \max_k \left[q_i^k + \beta \sum_{j=1}^{M} p_{ij}^k f_{n-1}(j)\right], \quad n = 1, 2, \ldots,$$

where $f_0(j) = 0$, $j = 1, 2, \ldots, M$. The relation $f_n(i)$ corresponds to the earlier definition of $f_n(R)$ with i implying the ith discrete level of R. Likewise, q_i^k, corresponds to the earlier definition of $q(A, R)$ with i implying the ith discrete level of R and k implying the kth discrete level of applied nitrogen A. The summation in equation (17) corresponds to taking the expected value of $f_{n-1}(\Phi(A,R,W))$ with respect to W;

see equation (2). (A copy of the all FORTRAN computer code and instructions on its use is available from the authors.)

Results

Optimal policies were obtained by solving the recursion relation (17) for selected forage prices and per-acre application costs. Nitrogen was assumed to cost \$.10 per pound and the interest rate used was 10%. An optimal policy specifies the amount of nitrogen to be applied for all combinations of stages and states (residual nitrogen). Results were obtained for planning horizons of one to fifty years. Obviously, it is not feasible to present the mass of numerical results in the available space. In general, the optimal policy had converged (become invariant to length of planning horizon) by stage seven. The numerical results are summarized in table 4. The optimal policies are presented using the S,s terminology of inventory control theory; s is the reorder point and S is the reorder level, that is, if the stock of nitrogen is greater than s, no nitrogen is applied in the present time period. However, if the stock of nitrogen is less than s, enough nitrogen is applied to return the total stock of nitrogen to the level denoted by S.

Scarf has proved that sequential decision problems of a particular structure always exhibit an optimal policy of the S,s type. It can be verified that the problem analyzed in this study falls under the general structure specified in Scarf's theorem.

At Newell when forage is valued at \$20 per ton and fertilizer application costs are \$1.00 per acre, S is equal to 145 pounds and s is equal to 70 pounds. In order for a decision maker to follow this decision rule he would need a method to determine the level of plant-available nitrogen in the soil at the time he normally applies nitrogen, say early in April. Assume that the decision maker knows the level of nitrogen in the soil. If nitrogen is greater than s (70 pounds), he would not apply nitrogen. If the current level of nitrogen is less than s (70 pounds) he would apply enough nitrogen to bring the level after application up to S (145 pounds). Specifically, if the current nitrogen level was 60 pounds, he would apply 85 pounds. If the current level was 90 pounds, he would defer any application and recheck his nitrogen inventory the following spring.

Once a fertilizer policy has been selected, its application over time can be illustrated with an example. Let us examine the optimal policy where forage is valued at \$20 per ton, nitrogen costs are \$.10 per pound, and spreading costs are \$1.00 per acre. The optimal policy in this situation in S,s format is 145, 70. The period 1942–51 is used for illustration because it contains wide variation in growing season precipitation. Assume that prior to 1942, no fertilizer has been applied; therefore, the decision rule indicates 145 pounds of nitrogen should be applied in the spring of 1942.

Table 4. Optimal Nitrogen Fertilization Policies

	Forage Price	Application Costs	Optimal Policy[a] S	s	Expected Annual Net Returns[b]
	(\$/ton)	(\$/acre)	(lb./acre)	(lb./acre)	(\$)
Newell					
	15.00		no nitrogen applied		4.95
	15.00	1.00	120	15	5.42
	15.00	1.50	120	10	5.25
	20.00		no nitrogen applied		6.60
	20.00	1.00	145	70	9.12
	20.00	1.50	150	60	8.83
Moccasin					
	15.00		no nitrogen applied		5.47
	15.00	1.00	170	110	11.67
	15.00	1.50	170	95	11.31
	20.00		no nitrogen applied		7.30
	20.00	1.00	180	130	18.82
	20.00	1.50	180	125	18.44

Note: The table values are based on an interest rate of 10% and nitrogen valued at \$.10 per pound.
[a] Figures rounded down to lower limit of interval for ease of presentation.
[b] Expected annual net returns are based on an initial state of no residual nitrogen.

The sequence of nitrogen applications and other information are summarized in table 5. Note that carry-over nitrogen and residual nitrogen are different names for the same thing. Nitrogen not used in the present time period is called residual nitrogen; it is carried over to the following time period and called carry-over nitrogen.

Residual nitrogen in 1942 (carry-over for 1943) is obtained from equation (4), given the values of growing season precipitation and total nitrogen. The optimal policy indicates that an application of nitrogen should be made in the spring of 1943 (s = 48 and is less than 70). The application should be 97 pounds, enough to restore the stock to S = 145.

There are some hazards in using the carry-over equation to estimate plant-available nitrogen over an extended period of time because errors in this equation could have a cumulative effect which would give poor estimates after a decade or so. The yield equation could be used as a check on predicted carry-over the previous year. Predicted yield from the estimated yield equation, with the available nitrogen variable set equal to the sum of predicted carry-over and applied nitrogen and the precipitation variable equal to observed precipitation, could be compared with observed yield. A discrepancy between these two yields of several standard deviations in the yield prediction equation would make predicted carry-over the previous year suspicious. More research is needed on using the estimated yield equation to estimate plant-available nitrogen, and thus get an updated estimate of residual nitrogen to which the carry-over equation could again be applied sequentially.

Returns to Fertilization

The returns figures of table 4 have been converted from present value of expected returns over an infinite planning horizon to a comparable expected annual net returns figure.

The financial returns to nitrogen fertilization vary quite widely (table 4) depending upon the shape of the yield-response function and the fertilizer-forage price ratio. An application cost of $1.00 per acre is used as the standard of comparison. If forage is valued at $15.00 per ton, nitrogen fertilization results in a modest increase in expected annual net returns over no fertilization, a 9.5% increase at Newell. Under identical conditions, expected annual net returns are more than doubled at Moccasin, from $5.47 to $11.67 per acre. At a value of $20.00 per ton for forage, fertilization is much more lucrative at Newell, resulting in a 38% increase in expected annual net returns over no fertilization. The comparable percenttage increase for Moccasin is 158%.

Examination of the profit-maximizing criterion for a nonstochastic case ignoring application costs reveals the optimal policies to be stable for given nitrogen-forage price ratios (Stauber and Burt, p. 901). Work at other locations with stochastic economic models considering application costs has indicated that the optimal policies are relatively stable for given nitrogen-forage price ratios. However, the profitability of fertilization increases directly with the forage price level for a given nitrogen-forage price ratio.

The effect of nitrogen spreading costs on optimal policies is not trivial. Increased application cost reduces the frequency of nitrogen

Table 5. Simulation of Nitrogen Applications for an Optimal Policy at Newell, South Dakota

Year	Carry-over Nitrogen	Nitrogen Applied	Total Nitrogen	Growing Season Precipitation	Forage Yield	Residual Nitrogen	Nitrogen Leakage	Carry-over Proportion
	(lb./acre)	(lb./acre)	(lb./acre)	(in.)	(lb./acre)	(lb./acre)	(lb./acre)	
1942	0	145	145	10.10	2664	48	97	0.331
1943	48	97	145	4.54	919	121	24	0.834
1944	121	0	121	8.56	2113	48	73	0.397
1945	48	97	145	7.01	1806	73	72	0.504
1946	73	0	73	15.45	2468	14	59	0.197
1947	14	131	145	7.18	1861	71	74	0.491
1948	71	0	71	7.91	1567	30	41	0.426
1949	30	115	145	4.16	766	134	11	0.922
1950	134	0	134	4.19	762	122	12	0.912
1951	122	0	122	5.59	1242	79	43	0.651

Note: S is equal to 145 pounds of nitrogen per acre and s is equal to 70 pounds of nitrogen per acre.

applications. This is indicated by an increase in S and reduction in s as application costs increase, that is, higher application costs encourage larger applications of nitrogen less frequently.

Sensitivity of Optimal Policies to Specification of the Carry-over Equation

The specification of the carry-over equation reported here is a generalization of the simple carry-over model used by Stauber and Burt. The parameter estimates for Newell did not vary significantly from an a priori specification that α_2 equals one and α_3 equals minus one. In contrast, at Moccasin the parameter estimates were significantly different from such an a priori specification (a_2 equals 1.2459 and a_3 equals -2.4772). As a check on the sensitivity of optimal policies to alternative specifications of the carry-over equation at Moccasin, the yield and carry-over equations were estimated under the constraints that α_2 equals one and α_3 equals minus one. The parameter estimates of the yield equation were substantially the same as those obtained from the general model. The fit, as evidenced by a standard error of the estimate of 303.3 pounds per acre versus 280.24 for the general model, was slightly inferior.

The important question, however, centers on how the alternative specifications affect the optimal policies. A comparison of the optimal policies derived from the alternative specifications of the carry-over equation indicates the effect on the optimal policies is trivial. If forage is valued at \$15.00 per ton, the optimal policy for the constrained model specifies a stocking level of 160 pounds per acre and a reorder level of 90 pounds per acre; the values for the general model are 170 and 110. If hay is valued at \$20.00 per ton, the optimal policies are quite similar, the only difference being a reorder level 5 pounds per acre less for the constrained model.

This convergence to quite similar policies as the price of forage increases is plausible. The possible economic loss of being understocked on nitrogen becomes the dominant consideration and overshadows the physical considerations involved in the specification of the carry-over equation.

In summary, the optimal policies are not extremely sensitive to alternative specifications of the carry-over equation. In addition, as the profitability of fertilization increases through a more favorable nitrogen-forage price ratio, the sensitivity diminishes.

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Equilibrium Quantity and Timing of Mexican Vegetable Exports

Richard L. Simmons and Carlos Pomareda

Mexico has recently expanded its exports of tomatoes, peppers, and cucumbers to the United States. In order to evaluate possibilities for further expansion, a linear programming production model for specific regions in Mexico was constructed and tested. Various equilibrium situations were analyzed to appraise possible future trends. Special features of the model were the inclusion of risk, demand functions for all crops, and allowance for both competitive and monopolistic supply structures. It was concluded that rising wage rates and tighter supply controls would halt Mexico's expansion of export winter vegetables.

Key words: linear programming, Mexican export vegetables, risk aversion, monopoly, partial equilibrium.

Florida's principal competitor for the U.S. winter market for fresh tomatoes, cucumbers, and bell peppers is Northwest Mexico. From 1968 to 1973 Mexico's share of this market increased from 32% to 58% largely at Florida's expense (USDA, *Fresh Fruit and Vegetable Shipments*). An appraisal of the effects of changing economic factors on Mexico's future production potential is necessary to help formulate U.S. trade policy.

This study develops a model of aggregate producer behavior in Mexico's export winter vegetable regions and uses it to evaluate the impact of changes in economic factors on equilibrium timing and quantity of tomato, pepper, and cucumber exports. The model takes monthly net import demand functions in the U.S. and Canada as given and uses linear programming to generate static industry equilibria under a range of alternative specifications concerning risk, competitive supply structure, and wage rates. Since vegetable prices are endogenous to the model, equilibrium U.S. prices and Mexican production are simultaneously generated.

The Problem

Two regions in the Mexican state of Sinaloa, Culiacan and Fuerte Sur, are analyzed. Together these two regions comprised 90%, 88%, and 80% of Mexico's tomato, pepper, and cucumber exports in 1971–72 (Union Nacional de Productores de Hortalizas). Although the regions are approximately 100 miles apart and have somewhat different climates, each can produce a wide variety of intensive, irrigated crops on a year-round basis. It was necessary to include a full range of production alternatives in the analysis, omitting only livestock and perennial crops.

The timing of vegetable plantings and the resulting shipment pattern is important in determining total annual net revenue. Intra-seasonal changes in demand interact with changes in production conditions, yields, and costs to determine a conceptual optimum program of plantings over the season. The structure is further complicated by the opportunity to divert export tomatoes into the domestic market. Although input requirements generally reflect a machine-oriented, high technology production method, the harvesting of cotton and vegetables and part of the weeding is done by hand. Tomatoes are grown both as staked and unstaked (ground tomatoes). Ground tomatoes use less fertilizer, are picked less frequently, yield about one-third as much as staked tomatoes, and involve lower investment costs and less risk of large negative net returns. Less frequent picking saves labor and allows substitution of other inputs for labor in the face of rising wage rates.

Returns from the production of export vegetables are notoriously variable and it was considered necessary to include risk as a fac-

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tor affecting decisions in the model to avoid overstatement of vegetable supplies relative to the less risky traditional crops.

By virtue of national and state producer organizations, export vegetable producers in Mexico were able to exert direct control over plantings for the first time in the 1973–74 season, after several years of reliance on quality controls, shipping holidays, and informal coercion. The actual degree of monopoly power both before and after institution of planting controls is a matter for question. This study compares equilibrium shipments under a competitive structure, which implies P = MC for each activity, with those under a monopoly structure implying MR = MC for each activity. A comparison of the solutions under the two alternative specifications with actual 1972–73 plantings is used as an informal test of the hypothesis that Mexican producers acted competitively prior to the enactment of the 1973–74 controls.

One of Mexico's production advantages has been low farm wages. Recent government concern about farm income caused a doubling of minimum farm wage rates from 1968 to 1974, and further rapid increases are likely. With current technologies for vegetables, labor comprises about 40% of total production costs. Hence, wage rates are important in determining future production trends. The wage rate is entered at levels ranging from 36 to 70 pesos per day to determine the effect on optimal solutions.

The Model

The model draws heavily on the work of Duloy and Norton, Hazell, and Hazell and Scandizzo. The objective function is

$$\max \Pi = X'W(A - 0.5\,BWX) - C'X - \phi(X'\Omega X)^{1/2},$$

where X is a vector of aggregate activity levels, in hectares, W is a diagonal matrix of average yields, C is a vector of cost coefficients, A, B are the coefficient matrices of the linear demand structure $P = A - BXW$, where market quantities (Q) equal WX (all individual demand functions are assumed independent), ϕ is a risk aversion coefficient, and Ω is a variance-covariance matrix of gross activity returns.

Hazell and Scandizzo show that this formulation yields solutions corresponding to industry equilibrium under perfect competition in the sense that P = MC for each activity. They show that MC contains a marginal risk element in addition to the marginal factor cost and represents the additional expected return demanded by farmers as compensation for taking risk. The supply curves which include risk thus lie above the supply curves in the deterministic case and reduce equilibrium supplies accordingly. The risk aversion coefficient relates to the amount of risk compensation which farmers demand. The limiting case of $\phi = 0$ implies no risk aversion, which gives the deterministic solutions.

Conceptually, ϕ is an aggregation of the risk aversion coefficients of individual microunits. No attempt was made in this study to estimate ϕ values for either the microunits or the corresponding aggregate coefficient. Instead, alternative levels of ϕ were used to determine the sensitivity of the optimal solution as ϕ varies and to determine the value of ϕ which yielded solutions most closely corresponding to real world situations.

For the monopoly case the objective function was modified as follows:

$$\max \Pi = X'W(A - BWX) - C'X - \phi(X'\Omega X)^{1/2}.$$

Duloy and Norton show for the deterministic case the correspondence of this formulation with the monopoly condition of MR = MC for each activity. The addition of the risk element is straightforward following the interpretation of MC given above for the competitive case.

The objective function is quadratic but was linearized by a separable linear programming procedure as set forth by Duloy and Norton. The measure of variability in activity gross returns used in this study was the mean absolute deviation, a method first proposed by Hazell and later adapted in Hazell and Scandizzo. An estimate of the variance of the set of activities based on the mean absolute deviation is

$$(1)\quad \mathrm{est}(X'\Omega X) = \Delta\left\{\frac{1}{T}\sum_t\left|\sum_j (r_{jt} - \bar{r}_j)\, X_j\right|\right\}^2,$$

where $\Delta = \dfrac{T\Pi}{2(T-1)}$ is a correction factor to convert the square of the mean absolute deviation to an estimate of the population variance (assuming the population is normally distributed). The measure used in this study was not the estimate of the variance but rather the estimate of the standard deviation, i.e.,

$$(2) \qquad \frac{\sqrt{\Delta}}{T}\,\{\sum_t|\sum_j(r_{jt}-\bar{r}_j)X_j|\}.$$

This formulation was entered in the objective function according to the procedure of Hazell and Scandizzo by defining new variables, $Z_t \geqslant 0$, all t, and forming the problem, min $\sum_t Z_t$ such that $\sum_j(r_{jt}-\bar{r}_j)X_j + Z_t \geqslant 0$, all t.

The Z_t variables then measure the negative deviations in total revenue from the mean for the activity revenue outcomes, and $\sum_t Z_t$ is the sum of the negative deviations over all t. Obviously $2\sum_t Z_t$ is the sum of absolute deviations, which is the expression in braces in equation (2). The *LP* tableau given by Hazell and Scandizzo appropriately describes this model, except that they used the mean absolute deviation estimate of the variance instead of the standard deviation, which required evaluation and linearization of Z^2.

Product Demands

Monthly demand equations were estimated for tomatoes, peppers, and cucumbers for the winter season. The winter season was defined as December through May for tomatoes and December through April for peppers and cucumbers. The procedure followed was similar to the one used by Castro and Simmons.

The statistical model was a single-equation, least-squares, pooled data type using dummy variables to allow for changes in intercepts and coefficients of explanatory variables. Price was the dependent variable and quantities shipped and income were assumed predetermined. The form of the demand functions was assumed linear to facilitate subtraction of marketing costs. Hypothesis tests indicated that monthly slopes and intercepts were significantly different for all three products.

Demand equations for peppers and cucumbers used Florida shipping point prices, and the demand equations for tomatoes used Nogales prices for "breakers and riper, 5 × 6's and larger." The use of retail or wholesale prices would have involved the estimation and subtraction of a complex system of commission, brokerage, and shipping charges in order to derive the on-farm demand.

Supplies from Florida and other production areas (average of last three years) were subtracted from the estimated demand functions to obtain estimated import demand functions. Then, marketing charges including the sales commission of 12%, the U.S. tariff, and transport costs from Culiacan to Nogales were subtracted from the import demand functions to obtain at-plant demand functions at the Culiacan level. Finally, demand functions at the Culiacan level were converted to terms of pesos per kilogram. The resulting demand functions for export vegetables are given in table 1.

The Mexican demand functions for tomatoes and other crops were estimated by using the direct price elasticities given by Duloy and Norton (p. 317) and passing the demand equation through the 1972 price-quantity equilibrium points. Time-series quantity data were not available to statistically estimate equations. The demand for tomatoes in Mexico was assumed equal in all of the months included. Mexican demand functions for peppers and cucumbers were omitted from the model because these products are not produced in these regions in significant quantities for Mexican consumption. Demand functions for traditional crops and for tomatoes in Mexico are in table 2.

The model allows the Mexican market to absorb nonexportable qualities of tomatoes as well as transfers of exportable qualities according to the principles of optimal market allocation.

Production Data

Each region is treated as a single, aggregate decision unit, implying homogeneity in re-

Table 1. Estimated Demand Functions for Export Vegetables FOB Culiacan, Mexico

Product	Month	Demand Equation[a]
Tomatoes (U.S. and Canada)	Dec.	$P = 3.351 - 0.000043755\,Q$
	Jan.	$P = 3.184 - 0.000036722\,Q$
	Feb.	$P = 2.856 - 0.000020254\,Q$
	Mar.	$P = 4.309 - 0.000044305\,Q$
	Apr.	$P = 3.229 - 0.000019006\,Q$
	May	$P = 3.533 - 0.000039815\,Q$
Peppers	Dec.	$P = 1.905 - 0.00046591\,Q$
	Jan.	$P = 4.270 - 0.00040690\,Q$
	Feb.	$P = 5.092 - 0.00026592\,Q$
	Mar.	$P = 5.968 - 0.00035203\,Q$
	Apr.	$P = 5.896 - 0.00042629\,Q$
Cucumbers	Dec.	$P = 1.752 - 0.00016589\,Q$
	Jan.	$P = 2.419 - 0.00011539\,Q$
	Feb.	$P = 2.636 - 0.00009907\,Q$
	Mar.	$P = 3.121 - 0.00015937\,Q$
	Apr.	$P = 1.591 - 0.00008637\,Q$

Source: Price data were taken from USDA, *Fresh Fruit and Vegetable Prices*. Quantities were based on USDA, *Fresh Fruit and Vegetable Shipments*.

[a] Price is measured in pesos per kilo and Q in metric tons.

Table 2. Demand Functions for Mexican Crops

Crops	Demand Equation[a]	Direct Price Elasticity
Tomatoes	$P = 2.993 - 0.00008372\ Q$	−0.5
Sesame	$P = 3.068 - 0.00011210\ Q$	−1.2
Cotton	$P = 3.276 - 0.00000537\ Q$	−0.5
Rice	$P = 2.960 - 0.00001536\ Q$	−0.3
Safflower	$P = 2.069 - 0.00000531\ Q$	−1.2
Beans	$P = 5.573 - 0.00008800\ Q$	−0.3
Chickpeas	$P = 3.448 - 0.00007409\ Q$	−0.3
Corn	$P = 1.126 - 0.00001938\ Q$	−0.2
Sorghum	$P = 1.185 - 0.00000208\ Q$	−0.3
Soybeans	$P = 2.334 - 0.00000423\ Q$	−1.2
Wheat	$P = 0.936 - 0.00000107\ Q$	−0.5

Source: Price elasticities were taken from Duloy and Norton. Mean prices and quantities were taken from Secretaria de Recursos Hidraulicos.

[a] Price is measured in pesos per kilo, Q in metric tons.

source quality within the region and a relative absence of restrictions in resource combination in the individual microunits. The principal resource restrictions for each region are monthly land and water supplies and an annual water restriction. Other input supplies are assumed to be perfectly elastic at existing market prices. The only link between the two areas is through the demand constraints.

Most of the input-output data for cropping activities was taken from unpublished budgets prepared by the Confederacion de Asociaciones Agricolas del Estado de Sinaloa (ÇAADES) and was verified in part by several informal field visits. The yield distributions of staked tomatoes by months over the harvest season were estimated from unpublished experimental data obtained from the Centro de Investigaciones Agricolas de Sinaloa. Variation in gross revenue per hectare for all crops over six cropping years was taken from published CAADES bulletins. Table 3 indicates the large variation in gross revenues per hectare of export vegetables compared with traditional crops.

Estimates of water requirements and availabilities in the two regions were obtained from the Secretaria de Recursos Hidraulicos. Good measures of water requirements by months for specific crops are scarce and the water constraints are considered the weakest part of the data base. However, equilibrium acreages of vegetables are not greatly affected by inaccuracies in the water constraints.

Solutions

The first set of solutions used the 1972–73 wage rate of 36 pesos per day, the objective function corresponding to the competitive case, and risk aversion levels of 0, 0.5, 0.75, 1.0, and 1.5. Equilibrium acreages for each solution were compared with actual acreages planted in 1972–73 to determine the level of ϕ which resulted in the solution most closely corresponding to actual plantings. The results

Table 3. Variation in Gross Revenues, Total Costs, and Input Requirements per Hectare for Cropping Activities

	$\sum_{t=1}^{6} \lvert r_x - \bar{r}_j \rvert$		Total Costs per Hectare[a]		Annual Water Requirements	Labor Requirements
Crops	Culiacan (pesos)	Fuerte Sur (pesos)	Culiacan (pesos)	Fuerte Sur (pesos)	Both Regions (10,000 m.^{3})	Both Regions (man-days)
Tomatoes	99,204	68,405	41,175	36,236	0.960	133.0[b]
Peppers	134,178	92,878	22,500	21,020	0.960	132.0[b]
Ground tomatoes	—	26,396	—	13,893	0.710	28.2[b]
Cucumbers	58,731	33,792	16,418	10,065	0.470	19.7[b]
Sesame (spring)	997	889	2,112	2,064	0.820	15.8
Sesame (summer)	997	889	2,112	2,112	0.650	15.8
Rice	2,916	2,834	2,227	3,235	1.950	9.7
Safflower	3,662	3,293	1,678	1,704	0.700	3.9
Beans	2,389	2,114	2,160	2,170	0.890	14.1
Chickpeas	3,796	3,274	2,586	2,614	0.990	10.7
Corn (summer)	997	724	2,052	2,212	0.910	18.4
Corn (winter)	997	724	2,052	2,212	0.840	18.4
Sorghum	3,220	1,456	2,574	2,629	0.790	9.5
Soybeans	3,174	3,537	2,110	2,159	0.960	5.4
Wheat	2,009	1,922	2,510	2,540	0.880	9.6
Cotton	—	3,830	—	6,022	—	72.2

[a] Wage rate of 36 pesos per day.

[b] Preharvest labor only.

Table 4. Comparison of Actual 1972–73 Plantings with Equilibrium Solutions, Competitive Case, Wage of 36 Pesos per Day

	Equilibrium Planted Area (hectares)					1972–73 Actual
Crops	$\phi = 0$	$\phi = 0.5$	$\phi = 0.75$	$\phi = 1.0$	$\phi = 1.5$	(hectares)
Tomatoes	19,239	15,709	14,317	13,356	9,217	16,382
Peppers	3,633	3,332	3,309	3,128	2,440	4,869
Cucumbers	3,177	2,803	3,177	3,447	3,552	5,614
Sesame	0	3,194	3,790	4,386	4,983	4,883
Rice	33,047	34,733	34,733	33,890	33,047	33,047
Safflower	96,986	65,196	48,825	43,219	29,885	51,837
Beans	33,555	33,555	32,165	32,166	30,350	47,192
Chickpeas	13,352	14,989	14,147	13,730	12,897	25,580
Corn	14,875	18,769	18,769	18,769	18,769	21,503
Sorghum	55,717	54,749	55,550	46,552	47,495	68,608
Soybeans	104,037	104,170	89,355	79,478	79,478	75,048
Wheat	26,552	39,588	25,034	25,034	10,479	45,620
Cotton	57,024	46,210	42,605	39,001	31,792	37,056

are presented in table 4. No single level of ϕ is best for all crops. For export vegetables, chickpeas, beans, and wheat, the level of $\phi = 0.5$ seems best. For other crops, higher levels of ϕ give solutions more closely corresponding to actual acreages. Since the emphasis of this study is on the three export vegetables, the level of $\phi = 0.5$ was selected for use in subsequent solutions.

Using the objective function corresponding to the monopoly case for export vegetables, solutions were also generated for the same levels of ϕ and the same wage rate as for the competitive case just described. These solutions are presented in table 5. For all levels of ϕ, optimal acreages of the three vegetables were unrealistically low when compared with actual plantings. It was thus concluded that vegetable producers were operating in the context of a competitive environment in 1972–73. The monopoly solution indicates the possible future trend in planted acreages if, in fact, recent controls enacted by the vegetable producers have created significant monopolistic characteristics.

The competitive case with a risk aversion level of 0.5 is used in the remainder of the analysis.

Effect of Increased Wages on Vegetable Exports

The first comparison is the effect of increased minimum wages for farm labor on equilibrium plantings of export vegetables and other crops. These comparisons are given in table 6. An increase in the wage rate causes sharp decreases in equilibrium plantings of the three export vegetables and other relatively labor-

Table 5. Comparison of Actual 1972–73 Plantings with Optimal Solutions, Monopoly Case, Wage of 36 Pesos per Day

	Optimal Planted Area (hectares)				Actual 1972–73
Crops	$\phi = 0$	$\phi = 0.5$	$\phi = 0.75$	$\phi = 1.0$	(hectares)
Tomatoes	9,644	7,653	6,912	6,720	16,382
Peppers	1,921	2,047	1,879	1,936	4,869
Cucumbers	1,572	1,628	1,680	1,679	5,614
Sesame	810	0	3,790	4,386	4,883
Rice	33,890	33,047	34,733	33,890	33,047
Safflower	99,575	64,982	48,952	31,962	51,837
Beans	34,018	32,165	32,165	32,200	47,192
Chickpeas	13,352	13,730	13,730	13,314	25,580
Corn	14,875	18,769	18,769	18,769	21,503
Sorghum	55,717	55,717	50,855	50,855	68,608
Soybeans	111,460	104,243	87,969	75,614	75,048
Wheat	26,447	39,588	25,034	25,034	45,620
Cotton	57,024	24,583	42,605	35,397	37,056

Table 6. Effect of Increased Wage Rates on the Equilibrium Area Planted to Mexican Crops, Competitive Case, $\phi = 0.5$

	Area Planted (hectares)		
	Wage Rate (pesos per day)		
Crops	36	50	70
Tomatoes	15,709	13,174	8,695
Peppers	3,332	2,790	2,103
Cucumbers	2,803	2,439	1,870
Sesame	3,194	0	0
Rice	34,733	34,733	33,890
Safflower	65,196	63,298	63,298
Beans	33,555	32,165	30,333
Chickpeas	14,980	14,147	13,314
Corn	18,769	10,982	0
Sorghum	54,749	50,855	45,993
Soybeans	104,170	95,533	86,533
Wheat	39,588	25,034	9,449
Cotton	46,210	24,503	0

intensive crops such as corn and cotton. The average elasticities of the vegetable acreages in response to wage rate increases are −0.9 for tomatoes, −0.7 for peppers, and −0.6 for cucumbers. Clearly the government policy of rapid increases in rural wages will have a substantial impact on vegetable exports. A shift from the production of staked tomatoes to ground tomatoes was noted at the higher wage rates, indicating substitution of other inputs for labor. Further innovations in labor-saving techniques could modify the elasticity estimates somewhat. The quantitative effects of such innovations are difficult to predict accurately and inclusion of additional such activities in the model was not attempted.

Seasonal Distribution of Vegetable Exports

The equilibrium distribution of exports over the season is affected by monthly changes in demand and production costs and the normal pattern of competitive shipments from Florida and Caribbean countries. These three factors are taken into account in the model. Table 7 compares the equilibrium monthly distribution of tomatoes, peppers, and cucumbers exports over the winter season with the 1970–73 average actual pattern of shipments. An increase can be expected in December tomato shipments and a reduction in February and March if the differential in monthly production costs and demands are adequately represented and if the industry moves toward the equilibrium position according to the assumptions of competitive behavior. By using the monthly demand functions to estimate the expected prices for the equilibrium and actual quantities shipped each month, it was estimated that industry net revenue from tomatoes could be increased by 10% by adopting the equilibrium shipment patterns.

By comparing the normal shipment pattern for peppers with the equilibrium pattern, it can be concluded that shipments of peppers could be reduced in December and January and increased in March and April. Industry net revenue could be increased by 6% by so doing. Cucumber shipments appear excessive in December and January, months of heavy Florida shipments.

Allocation of Production between Export and National Market

Although tomatoes are grown primarily for the export market, about 30% of total field production is sold in Mexico. The Mexican market is normally used for nonexportable qualities and occasionally for diversion of exportable supplies when the U.S. market becomes temporarily oversupplied. Optimal allocation

Table 7. Equilibrium Monthly Distribution of Exports Compared to Actual Shipments

	Total Seasonal Shipments (metric tons)					
	Tomatoes		Peppers		Cucumbers	
Months	Equilibrium	Actual	Equilibrium	Actual	Equilibrium	Actual
Dec.	27,676	8,080	0	1,816	1,519	12,441
Jan.	30,458	27,211	2,015	7,419	7,964	13,357
Feb.	32,389	53,697	8,243	9,398	11,466	11,165
Mar.	44,247	59,381	8,715	7,550	10,171	11,557
Apr.	49,082	57,513	6,793	3,409	1,053	5,762
May	35,991	34,251	0	0	0	0
Total	219,843	240,133	25,946	29,592	32,173	54,282

of the crop between the two markets has not yet been pursued by producers. It is of interest to evaluate possibilities for increased income from allocation according to established maximization criteria.

In the absence of supply restrictions or quality differentials, the prices in two competitive markets tend to be equalized (net of handling costs) by the process of individual producer decisions to ship to the market yielding the highest price. The monopoly case is similar except that marginal revenues are equalized in the two markets instead of prices. The present model simulates this process by including a transfer activity to divert exportable supplies from the export market to the domestic market.

In the first set of solutions this nonexportable portion of total field production was entered at 30% in accordance with recent practice. Under these conditions, no transfers from the export market to the Mexican market were economical. The normal quantity of nonexportable qualities was sufficient in each month to keep the Mexican prices below U.S. prices and thus prevent price equalization. Given that nonexportable supplies are joint products with no current alternative use, any price above disposal costs is profitable.

To investigate the effects of a possible relaxation of export quality restrictions or a possible technological breakthrough which would increase the proportion of exportable fruit, the basic input data were changed to reflect a proportion of nonexportable quality of 20% of total field production. In this case exportable supplies were transferred to the domestic market in December, January, February, and May, and prices were equalized in the two markets according to principles of market allocation (table 8). However, in March and April, nonexportable supplies were still sufficient to keep the Mexican price below the export price and no transfers were made. Of course, additional work in estimating Mexican demand for tomatoes would make this type of allocation decision more precise.

Table 8. Equilibrium Allocation of Tomatoes between the Export and Mexican Market

	Quantities Sold (metric tons)		Net Farm Price (pesos per kilo)	
Month	Export	Mexican	Export	Mexican
Dec.	26,305	9,400	2.20	2.20
Jan.	30,921	10,665	2.10	2.10
Feb.	32,389	9,465	2.20	2.20
Mar.	49,859	12,459	2.10	1.95
Apr.	52,216	13,054	2.25	1.90
May	41,015	13,054	1.90	1.90

Note: Assumes exportable quality for 80% of total field production.

Conclusions

By using demand functions and risk factors for cropping activities in the mathematical programming model for Culiacan and Fuerte Sur, acceptable representations of actual aggregate behavior for the base year 1972–73 were obtained.

Equilibrium solutions were obtained for both the competitive and monopolistic case, and producer behavior in the base year 1972–73 corresponded more closely to the competitive case. Risk aversion coefficients (ϕ) of 0, 0.5, 0.75, and 1.0 were tested and the level of risk aversion corresponding to $\phi = 0.5$ appeared to function best in obtaining solutions most closely corresponding to actual plantings in 1972–73.

Using the competitive objective function and $\phi = 0.5$, the model was then used to evaluate possible effects on tomato, pepper, and cucumber exports of changes in wage rates and changes in the percentage of total production which is of exportable quality.

It was found that, given present technologies, an increase of 10% in the minimum daily wage would decrease exports by 9% for tomatoes, 7% for peppers, and 6% for cucumbers. Given present Mexican government policies of rapidly increasing the minimum farm wage, substantial decreases in vegetable exports can be expected (other factors such as Florida production assumed constant).

In general, it is concluded that the recent rapid expansion of Mexican exports of tomatoes, peppers, and cucumbers is over. Given the demands for competing crops in the export production areas, the rapidly rising labor costs in Mexico, and the institution of more effective supply controls starting in the 1973–74 season, it appears that some contraction in planted acreages of these three export vegetables can be expected.

Additional investigation of the monopolistic aspects of the model is warranted, including allowance for Florida adjustments.

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Systems Planning of Economic Development in Eastern Oklahoma

James Nelson and Luther Tweeten

A model which simulates the results of potential policy strategies directed toward alleviating problems of underdevelopment in rural areas is developed and utilized. For each strategy simulated, limited public funds are assumed allocable among various types of development activities (public assistance, human development, job development). Findings indicate that with a 30%–40% annual increase in development allocations, study area poverty can virtually be eliminated in no more than fifteen years. Public assistance and industrialization programs are found to be the necessary bases of potentially successful development plans.

Key words: simulation, development simulator, rural development planning, community development, regional economy, regional growth.

In many cases, "Overall Economic Development Programs" required by federal legislation for multicounty development districts have not been comprehensive. Planners have failed to view distressed rural areas as systems for which strategies or policies can be devised, comprised of the level and combination of public programs which meet development targets with efficient use of limited resources. Typical plans are especially deficient in socioeconomic planning, failing to identify public programs required to alleviate poverty and underemployment.

Systems planning (see Tweeten 1974b, for definition) of socioeconomic development can improve both classroom instruction and public policy in rural development. Economic evaluation of the efficiencies of various programs viewed in the context of systems planning, can help public policy decision makers decide which programs to expand and which to contract and what total level of funds is required to reach development targets. In the classroom, the systems approach, organized as a rural development game, allows students to gain experience in devising a development strategy. Students are made aware of the complicated relationships among demographic factors and policy activities within economic areas.

The purpose of this study is to develop and utilize a pilot exemplary model to simulate and evaluate the results of potential rural development policies. The formal objectives of the study are to (*a*) estimate technical efficiency coefficients for alternative area development activities, (*b*) devise a computerized simulation model depicting the economic development process and how it is influenced over time by public programs, and (*c*) evaluate the effectiveness of past and potential rural area development policy packages in attaining selected targets.

The process of economic development is simulated for the seven-county Eastern Oklahoma Development District located in the Ozarks Region. Development targets are to alleviate, within a reasonable time frame, the high rates of poverty and underemployment that characterize the district.[1] Federal programs are emphasized and the public cost of efficient strategies to reach these targets are generated. Results apply specifically to only one multicounty district but suggest directions for other multicounty districts characterized by high underemployment and poverty. The

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[1] By county, the underemployment rates in 1960 (Kampe and Lindamood) and poverty incidence rates in 1969 (U.S., Department of Commerce, Bureau of the Census) were the following: Adair 26%, 42%; Cherokee 26%, 28%; McIntosh 30%, 27%; Muskogee 17%, 21%; Okmulgee 5%, 23%; Sequoyah 20%, 28%; and Wagoner 18%, 18%.

development model used in this study has been used in the classroom to generate enthusiasm, experience, and feedback that are important for effective learning (Nelson and Doeksen).

The Model

We now turn to the content of the simulation model (see Nelson for computer program listing). Because the demographic, program-efficiency and other input data utilized in this study were not originally collected for use in systems planning, more than the usual number of assumptions are necessary to formulate the simulation model. On the whole, coefficients appear to be sufficiently reliable to draw preliminary conclusions concerning efficient rural development strategies.

The planning model simulates the economic development of a rural region over time as it is influenced by combinations of development programs. The population of the Eastern Oklahoma Development District is divided into sociodemographic categories based on income, work eligibility, age, and levels of education and training. A decision-making authority is assumed to have funds available on an annual basis for a variety of programs that affect the social and economic well-being of these subpopulations. Various combinations of programs comprising development strategies are entered into the simulation model. The model simulates changes in the population by births, deaths, and aging. It also simulates changes in the educational and training levels, migration and birth rates, income, and numbers of poor induced by special programs. At the end of each year, the output of the model describes the simulated situations of subpopulations and the simulated aggregate economic condition of the area.

Sociodemographic Data

Impacts of public programs depend on the sociodemographic characteristics of the developing area. The area population is cross-classified into twenty-one sociodemographic categories based on income, age, ability to work, and levels of education and training (table 1).

The poor in the area are classified according to their ability to work. Those capable of supporting themselves by working are classified as salvageable. Those incapable of supporting themselves by working are classified as unsalvageable. The poor are further classified by age and levels of education and training. The nonpoor in the area are classified by age and income level.

Table 1. Sociodemographic Data for the Eastern Oklahoma Development District, 1970

	Number of Persons	
Nonpoor	114,104	
Less than age 20		
School dropouts (low income)		1,376
Young children and students		38,609
Age 20–39		
High income (over $15,000 annually per family)[a]		2,931
Medium income ($8,000–$15,000 annually per family)		12,016
Low income ($4,000–$8,000 annually per family)		14,361
Age 40–64		
High income (over $15,000 annually per family)		3,535
Medium income ($8,000–$15,000 annually per family)		14,492
Low income ($4,000–$8,000 annually per family)		17,319
Age 65 and over		9,465
Poor (less than $4,000 annually per family)	77,090	
Unsalvageable		
Age 15–64		15,298
Age 65 and over		17,147
Young children and students		29,813
Salvageable		
Age 20–39		
With high school education and training		312
With high school education and no training		1,024
With training and no high school education		1,201
With neither high school education nor training		3,958
Age 40–64		
With high school education and training		362
With high school education and no training		1,205
With training and no high school education		1,407
With neither high school education nor training		4,633
Age 15–19		
With neither high school education nor training (school dropouts)		730

Source: U.S., Department of Commerce, Bureau of the Census (1971, 1972).

[a] For the level of aggregation of this study, specification of these income thresholds based on average family size was deemed sufficient.

Alternative Development Activities

Development funds in the area can be allocated among alternative activities directed toward alleviating poverty and generating income for the area's residents (fig. 1). These alternatives are special development activities over and above such conventional public investments in an area as roads, schools, and other services and infrastructure which appear to be adequate in the area. Spending of public funds on these items over and above the projected pattern would appear to have low economic payoff.[2] Of course the area is free to tax the additional economic base generated by economic development programs to provide additional services as residents see fit.

Unsalvageable poor are removed from poverty by continuous transfer payments. Upon reaching age sixty-five, unemployed salvageable poor are reclassified as unsalvageable poor.

Funds allocated to education keep students from dropping out of school. Funds allocated to technical training train untrained poor.[3] These activities do not provide direct earnings to the poor, but they do appreciably raise incomes when the individuals become employed.

Funds allocated to family planning reduce birth rates by making information and contraceptives available to the poor. Over time, this reduces the number of young children and students in poverty.

A portion of the jobs made available by industrialization and labor mobility subsidies are assumed to go to the poor. Among the poor, jobs go first to the best educated, best trained, and youngest. Local jobs made available by industrial development efforts are filled first; then jobs outside the region made accessible by labor mobility grants are filled.

[2] In general, studies show that adequate infrastructure is a necessary but not a sufficient condition for economic growth (Kuehn and West). Findings of White and Tweeten showed that differences in socioeconomic background of students rather than differences in quality of education accounted for low schooling achievement in underdeveloped areas of Oklahoma. No studies were available showing the portion of public investments in infrastructure such as roads and water and sewer systems going to the poor in underdeveloped areas.

[3] Vocational-technical schools currently operating in the multicounty study area have adequate existing capacity to train conventional students in skills required. Major expansion would not be profitable (Shallah and Tweeten).

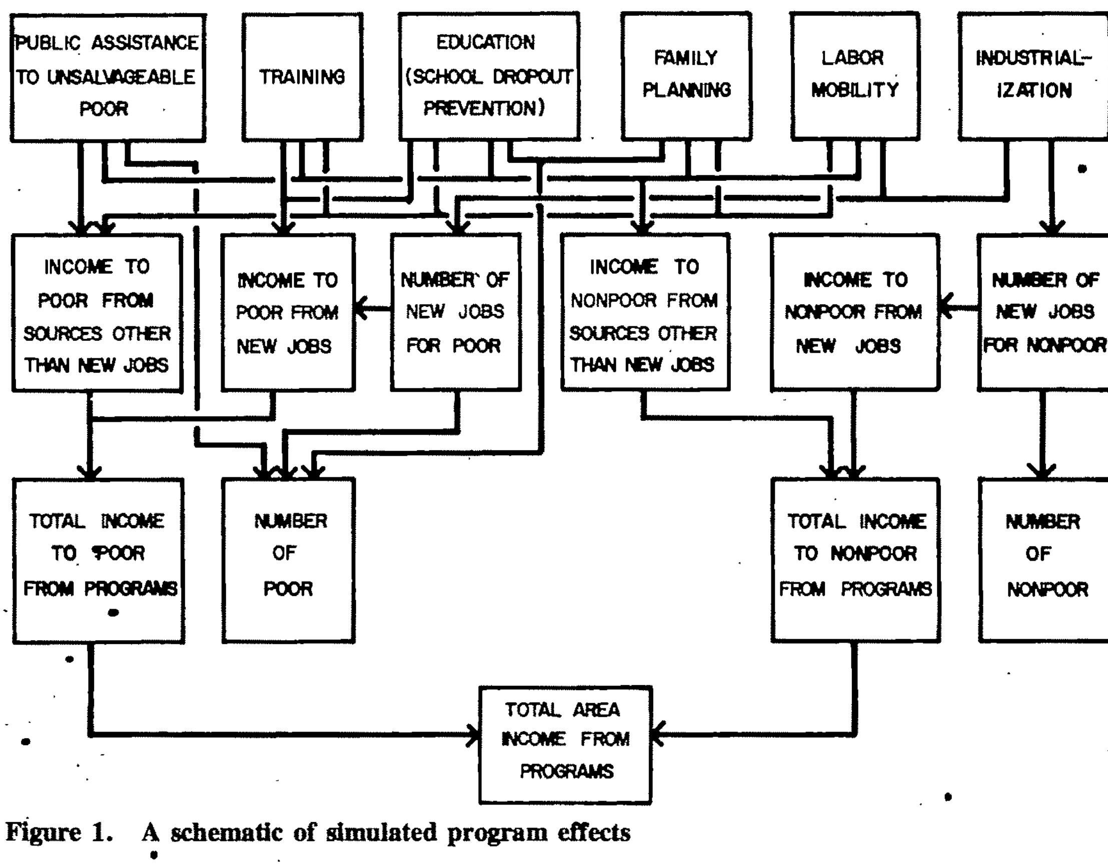

Figure 1. A schematic of simulated program effects

Wages paid those taking new jobs vary according to the levels of education and training of the workers. Wages of out-migrants are included in aggregate income of the development district. Some of the new jobs generated locally are filled by local nonpoor and some are filled by nonpoor who migrate into the area. Jobs vacated by the local nonpoor are assumed to be filled by the poor.

While funds allocated to activities other than industrialization do not create permanent jobs in the area, such expenditures do create income for both nonpoor and poor. Administrative costs and transfer payments are examples of funds assumed not to generate jobs directly but to add income for the district.

Technical Coefficients

Technical coefficients specified for the rural development simulator determine the economic and other changes which occur in the study area over the time period simulated. Some of these changes are affected by development activities, while others are independent of such activities. The population constitutes a dynamic environment, changing over time regardless of whether development activities are initiated in the area. The technical coefficients required for this simulator are of four types: demographic coefficients, income coefficients, employment coefficients, and development activity efficiency coefficients (see Nelson for full discussion).

Demographic coefficients in the model include birth rates, death rates, and a population growth rate (including implicit net migration rates apart from those influenced by the programs) for the study area. The income coefficients specified for the simulator include poverty income thresholds for sociodemographic categories of the study area population, potential earnings for the area's poor who take jobs created by development activities, total income resulting in the area per dollar of public funds spent on development activities, and the percentage of the area's income which goes to the area's poor. The simulator requires the specification of three coefficients descriptive of the labor force of the area considered. These employment coefficients include the percentage of working age adults in the labor force, the percentage of poor in the labor force who have jobs but are underemployed, and the percentage of under employment of the underemployed poor.

Estimates of effects of each development activity included in the simulator (activity efficiency coefficients) serve as a starting point for estimating total effects of strategies containing multiple development activities. Linkages become apparent. Skill training programs, for example, display low payoffs in the absence of programs to provide jobs locally or elsewhere. Development activity efficiency coefficients utilized in this study describe the impact, in terms of cost effectiveness, of labor mobility programs, industrialization programs, school dropout prevention programs, technical training programs and, family planning programs (table 2).

Results

The quantitative model was used to simulate the effects of alternative development strategies on the population of the eastern Oklahoma study area. In this section, the simulated results of alternative strategies are discussed and the strategies are compared and evaluated in light of development goals—alleviation of poverty and underemployment. Because underemployment is concentrated among the salvageable poor, alleviation of poverty also alleviates underemployment.

Poverty amelioration was measured by the number of years required for alternative strategies to eliminate poverty and by the person poverty years accumulated over the time horizon considered. Of these two measures, person poverty years accumulated is the most complete. It is defined as the sum, over all years simulated, of the number of people remaining in poverty in the study area at the end of each year. Thus, it is one measure of the relative effectiveness of alternative development strategies in removing people from poverty and keeping them out of poverty over time.

Simulated efficiencies of alternative strategies in generating income for the people of the study area were measured by two different efficiency ratios. These ratios included a ratio of present value of simulated total regional income generated by each strategy to the present value of simulated total public costs (including transfer payments) and a ratio of present value of simulated income generated for the study area's poor by each strategy (including transfer payments) to the present value of simulated public strategy

Table 2. Development Activity Efficiency Coefficients for the Eastern Oklahoma Development District

Labor mobility programs[a]	
Number of people moved to jobs per $1000 of public expenditure on labor mobility programs	1.070
Proportion of labor mobility allocation funds which go to purposes other than relocation assistance allowances (administration, training, and counseling)	0.66
Proportion of relocatees who remain outside study area permanently (limit to program attrition)	0.33
Proportion of relocatees who return to study area each year (until minimal attrition level is reached)	0.30
Industrialization programs[b]	
Number of jobs directly created per $1000 of public expenditure on industrialization programs	
Estimate 1 ("upper limit")	0.179
Estimate 2 ("most realistic")	0.105
Estimate 3 ("lower limit")	0.050
Total area jobs resulting per direct job generated by industrialization	2.3031
Proportion of jobs generated by industrialization which go to area's poor	0.33
New jobs going to workers outside the area as a percentage of new jobs going to people other than the area's poor	0.24
Proportion of jobs vacated by nonpoor workers which are refilled	0.78
Education programs, school dropout prevention[c]	
Number of potential dropouts kept in school per dollar of public expenditure on education programs	0.00025
Technical training programs[d]	
Number of people trained per dollar of public expenditure on training programs	0.000684
Family planning programs[e]	
Number of unplanned poor births avoided per dollar of public expenditure on family planning programs	0.0010204

[a] From Fairchild; Nelson and Tweeten.
[b] From U.S., Department of Commerce, Boise Cascade Center and Economic Development Administration; Childs; Kuehn et al.; Muncrief; Shaffer; Singer; Smith.
[c] From Borus, Brennan, and Rosen; Somers and Stormsdorfer; Woltman and Walton.
[d] From Shallah and Tweeten.
[e] From Kershaw and Courant.

costs. For all of the efficiency ratios, a discount rate of 6% was used.

Conceptually, these efficiency ratios are similar to, but not equivalent to, traditional benefit-cost ratios. The ratios calculated in this study do not include private costs nor do they account for all future benefits; hence, they are only indexes of income generation efficiency. They were only calculated over the fifteen-year planning horizon of the study (until all of the strategies that had the potential to alleviate poverty had done so). Because benefits beyond this fifteen-year horizon were not simulated, none were included in the efficiency ratios. Consequently, the efficiency ratios may be biased downward for programs such as family planning and school dropout prevention which have long-term effects.[4]

Strategies Simulated

The number of strategies which could be simulated was almost unlimited. To counter this problem, those development strategies which appeared to be the most reasonable and feasible from the standpoint of social, economic, and political practicality were simulated (table 3).

Preliminary work with the simulator indicated that the input coefficient of the number of jobs directly created per public dollar spent on industrialization is of critical importance to results of many strategies. Consequently, some of the strategies simulated included the same development activities as other strategies but were based on different assumptions about the cost effectiveness of industrialization programs.

To facilitate comparisons among programs by holding selected variables constant, a limit of annual funds available for all development activities of $75 million was imposed for the strategies simulated. For one of the strategies considered (strategy 1—continuing programs in effect in 1970), simulated annual allocations remained well under $75 million. For the other strategies, annual allocations were at this limit in early years, then decreased as development program effects were felt. This annual development allocation limit spreads development strategy results over a longer, more realistic period. "Overnight" development would likely result in undesirable political, social, and physical disruptions in an area even if it were technically and economically feasible.

A first objective for development activities in the study area was to remove from poverty those poor who, for reasons of mental or physical incapabilities, could not work to support

[4] The ratios consider only public costs and associated incomes generated and hence do not reveal whether strategies are consistent with overall economic efficiency. Except for public assistance, each of the activities in the various strategies have been evaluated for overall economic efficiency in the studies reported earlier from which the coefficients were derived. In each instance, social (public and private) benefits exceeded social costs.

themselves (unsalvageable poor). Almost $50 million was allocated to this purpose (public assistance) in the study area in 1970 (U.S., Office of Economic Opportunity). Preliminary work with the simulator indicated that grants totaling almost $72 million per year in the early years of a development planning horizon are required to remove all of these unsalvageable poor from poverty. To appreciably reduce underemployment and poverty among salvageable poor in the area within a meaningful time horizon (less than twenty years), annual development allocations of from $2 million to $4 million in excess of allocations to unsalvageable poor are necessary.

Total annual public development expenditures on education and training were limited to 1970 allocations ($1,713,722). First priority for these funds went to education to decrease the area's school dropout rate for poor students to the level of the nonpoor rate (less than $50,000 each year), with the remainder going to technical training as long as there were untrained salvageable poor in the area. Annual expenditures, less that $560,000 per year, on family planning were limited to the amount necessary to decrease the area's poor birthrate to the level of the nonpoor rate.

Funds remaining after any allocation to unsalvageable poor, education, training, and family planning were allocated to labor mobility and industrialization. All salvageable poor, except those between ages fifteen and nineteen without high school education or training, were assumed eligible for labor mobility subsidization. Labor mobility allocations were limited by that total (not annual) amount of funds which would give all eligible poor one opportunity to move to jobs outside the area.

As shown in table 2, three different estimates of cost effectiveness for industrialization programs were calculated. For strategies 1–8, the middle estimate ($9,538 of public funds per direct job created) was assumed; for strategies 9 and 10 the upper estimate ($5,582 of public funds per direct job created) was assumed; and for strategies 11 and 12 the lower estimate ($20,000 of public funds per direct job created) was assumed. Strategy 13 included no allocations to industrialization.

Strategy Comparison and Evaluation

All but two of the simulated development strategies virtually eliminated poverty and underemployment in the study area in fifteen or fewer years (table 3). The two exceptions were strategy 1, which did not provide sufficient welfare grants to raise the incomes of the area's unsalvageable poor to the poverty threshold, and strategy 13, for which it was assumed that job creation by industrialization was infeasible. The only simulated poverty in the area beyond the point of virtual poverty elimination for the other 11 strategies resulted from the few children of unsalvageable poor who entered the area labor market each year and did not find jobs immediately. Such poverty is primarily a structural phenomenon. However, even when poverty has been reduced to structural poverty, unsalvageable poor must still receive continuous public support to stay out of poverty. So beyond the point of eliminating all but structural poverty for any strategy, simulated development allocations still went to welfare or public assistance grants for the full time simulated (fifteen years). Also, enough funds went to industrialization to provide jobs for the structurally impoverished. In reality, these industrialization funds might not be necessary, since self-sustaining economic growth might create enough jobs for these people.

Among strategies which virtually eliminated poverty, some eliminated poverty quicker than others. All yielded different ratios of present values of area income and income to the poor to present value of total public costs of development programs. The differences in final strategy results can be explained by the different development activities and industrialization cost effectivenesses assumed for various strategies.

Given the assumptions of the model, poverty could be eliminated in the study area in no more than fifteen years by annually allocating no more public funds to nonwelfare development activities than were allocated in the area in 1970 (approximately $5 million), if sufficient funds were allocated to welfare grants to raise the incomes of the area's unsalvageable poor to the poverty threshold. Public assistance and job development programs were found to be necessary components of successful development strategies. However, alone, neither of these activities was sufficient to alleviate poverty efficiently. Rather, they must be utilized together in conjunction with human resource development programs that supplement ongoing local and state education and training programs.

A development strategy containing all of the

Table 3. Summary of Simulated Final Results of Strategies Considered

Strategy[a]	Assumed Industrialization Cost Effectiveness[b]	Years Required to Substantially Eliminate Poverty	Person Poverty Years Accumulated	Present Value of Total Income Generated[c] ($ million)	Efficiency Ratio 1[d]	Efficiency Ratio 2[e]
1	*M*	poverty not eliminated	815,666	807	1.59	1.51
2	*M*	12	182,988	1,169	1.46	1.38
3	*M*	11	190,932	1,050	1.39	1.31
4	*M*	9	142,786	1,085	1.45	1.38
5	*M*	9	130,024	1,095	1.48	1.42
6	*M*	9	141,324	1,086	1.46	1.40
7	*M*	9	98,756	1,142	1.55	1.48
8	*M*	9	129,749	1,103	1.49	1.43
9	*U*	7	69,654	1,186	1.64	1.57
10	*U*	6	85,316	1,160	1.60	1.54
11	*L*	15	190,474	1,140	1.39	1.33
12	*L*	15	229,286	1,051	1.28	1.22
13	no industrialization allocations	poverty not eliminated	357,906	888	1.20	1.11

Note: Results are for year 15—the final year simulated.

[a] Programs included in the individual strategies were as follows:
strategy 1—limited welfare, education, training, limited industrialization (programs in effect in 1970).
strategy 2—welfare, training, education, family planning, labor mobility, industrialization.
strategy 3—welfare, training, education, family planning, industrialization.
strategy 4—welfare, education, family planning, industrialization.
strategy 5—welfare, education, industrialization.
strategy 6—welfare, family planning, industrialization.
strategy 7—welfare, labor mobility, industrialization.
strategy 8—welfare, industrialization.
strategy 9—welfare, labor mobility, industrialization.
strategy 10—welfare, industrialization.
strategy 11—welfare, labor mobility, industrialization.
strategy 12—welfare, industrialization.
strategy 13—welfare, training, education, family planning, labor mobility.

[b] *M*—Middle estimate of cost effectiveness ($9,538 public funds required per direct job created).
U—Upper estimate of cost effectiveness ($5,582 public funds required per direct job created).
L—Lower estimate of cost effectiveness ($20,000 public funds required per direct job created).

[c] Present value, over the planning horizon simulated, of total area income generated by development activities, including incomes of labor mobility relocatees living outside the study area.

[d] Ratio of the present value of total regional income generated by development programs to the present value of total public costs of the programs.

[e] Ratio of the present value of income to the poor generated by development programs to the present value of total public costs of the programs.

development activities (strategy 2) could alleviate poverty and underemployment in the study area over the fifteen-year planning horizon and could yield efficient income streams (benefits in excess of costs). Such a strategy provides program diversification, thus promoting complementarity among development activities. This strategy entails public assistance grants to provide minimum nonpoverty incomes for the unsalvageable poor and job development activities (labor mobility subsidization and industrialization) to eliminate underemployment. Political considerations might reduce or eliminate labor mobility programs on grounds that they encourage outmigration of an area's youth, deplete a surplus labor pool, or are inconsistent with programs to create jobs within the area.[5] A similar strategy to the one discussed above, but excluding labor mobility programs (strategy

[5] Arguments by an area's nonpoor (especially employers) that labor mobility programs encourage out-migration of an area's youth and deplete an area's surplus labor pool may be valid. However, the argument that such programs are inconsistent with programs to create jobs within the area seems less well founded. Labor mobility programs can have much more rapid effects in removing salvageable poor from poverty than can industrialization programs. However, labor mobility programs typically have high attrition rates. Consequently, short-run labor mobility programs may be consistent with long-run area industrialization activities. Mobility programs generate income while industrial development is getting started and provide a source of labor for local industry as workers return home. It is far more efficient from an economic standpoint, though not necessarily from a social standpoint, to hold the reserve labor supply awaiting local jobs in distant employment than in local underemployment.

3), would be less effective but could still eliminate poverty and yield returns in excess of public costs.

Strategies containing post-high school technical training programs, school dropout prevention programs, and family planning programs were less effective in eliminating poverty or generating income than similar strategies with these activities excluded. However, the complementary effects of these programs on job development and public assistance activities may not be fully accounted for in the model. Also, the results of such programs are often considered highly socially desirable. It does not appear that they should necessarily be avoided in planning for area economic development.

Conclusions

Regardless of the other programs included in rural area development strategies, if alleviation of poverty and underemployment are major goals, efficient strategies must include public assistance grants and job development. While much poverty can be eliminated among salvageable poor by job development, poverty can be eliminated among the unsalvageable poor only by welfare grants. For a development strategy to be effective in eliminating underemployment in a depressed area, job development activities are important and, if continued for a sufficient period of time, may generate a critical mass of self-sustaining economic activity. Other development activities (primarily human resource development) may be supportive of job development activities and have other results which are socially or politically desirable. But improvement of human, natural, or public resources yields favorable returns only as these resources are gainfully employed.

For the study area, allocations to public assistance grants totaling almost $72 million per year in the early years of a development plan are required to bring incomes of all unsalvageable poor to the poverty threshold. These funds constitute the bulk of development funding. Comparatively small annual allocations to other development activities (especially job development) of only $2 million to $4 million could appreciably reduce poverty among salvageable poor in the area. For underdeveloped areas where job development is feasible but not actively pursued, the public may be overlooking a chance to use comparatively few economic development funds on job development to yield relatively large payoffs in terms of poverty amelioration and income generation. The use of job development programs without the support of massive welfare-type programs would create a problem of income distribution between salvageable and unsalvageable poor. But, given severely limited funds, such action appears to be an efficient way to reduce poverty, and it would contribute to alleviation of the overall problem of poor-nonpoor inequity in our society.

Provision of sufficient public assistance to unsalvageable poor to reach poverty thresholds requires careful screening to separate salvageable from unsalvageable poor and poses severe administrative problems. Studies of negative income tax experiments in Iowa and North Carolina reveal that income guarantees exceeding 75% of the poverty threshold and implicit tax rates in excess of 50% engender strong long-run disincentive effects (Tweeten 1974a). Allowances for these considerations by providing smaller public assistance payments in the strategies considered in this study would enhance the efficiency ratios shown in table 2 and would not change the relative rankings of programs in reaching development targets but would leave more poverty remaining in the study area.

While some of the findings, such as the payoffs from various development activities, will be relevant to plans for other depressed areas, one obvious limitation of this analysis is that the results specifically apply only to the study area. Specific results of alternative development strategies are dependent on the particular income, employment, and sociodemographic situations of areas to which such strategies are applied. Public funds and time required for development programs to attain a critical mass of self-sustaining economic activity vary among underdeveloped areas.

This study was also limited by lack of data describing the effects of alternative development activities. For some types of activities, no information was available, so the activities were not included. For activities for which information was available, precision fell much short of that desired.

For the most part, data are unavailable for estimating economic payoffs from state or federal subsidies to develop area infrastructure such as transportation, water, and sewer systems. No studies were available showing the distribution of benefits from such infra-

structure among income groups nor the effectiveness of such investments in generating jobs. Also, no information was available on the effects of public processes (e.g., by the Extension Service) to initiate and maintain local planning and development organizations in underdeveloped areas. Cost effectiveness data would make it possible to include these activities in a systems model.

Although the most complete and current information was used insofar as possible, data describing the effects of education (school dropout prevention) programs and family planning programs were much less comprehensive than desired. However, both activities affect only a small part of the population. Further research could provide information useful in more definitively assessing the potential contributions of these and other area development programs to area subpopulations and also could provide data on chance or random elements to include in a stochastic model of development.

Price decreases for the output of newly developed industries or increases in public costs of programs to generate jobs could result in diminishing returns to industrial development activities. Such diminishing returns are not directly accounted for in the model. However, aggregate effects should not be a problem if development programs are focused on only a few depressed areas with potential for eventual self-sustaining progress given a critical mass of assistance. The study area appears to have such potential. Other areas lacking transportation facilities, natural resources, adequate population, or a growth center may not have such development possibilities. It was assumed that the types of development activities considered would, at most, only be initiated in a few underdeveloped areas dispersed throughout the nation. As a critical mass of self-generating development is reached in economic districts, priority for funds would be shifted to other districts characterized by underemployed resources. It was further assumed that there is a sufficient number of expanding local firms or mobile outside industries willing, if subsidized, to locate in such areas so that cost effectiveness coefficients would not change appreciably as more jobs are brought into the area.

Conventional evaluations of development activities examine only one level of cost (input) and returns (output). Typical studies also give little attention to the distribution of costs and benefits among economic and sociodemographic groups. These traditions will need to change if systems planning for area development is widely applied.

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The Political Economy of Rural Development In Latin America: An Interpretation

Alain de Janvry

The theory of unequal exchange between center and periphery is extended to provide an interpretation of rural underdevelopment in Latin America. It serves to explain both the causality of agricultural stagnation under dominance of the *latifundio* and the economic functionality of the subsistence sector where rural poverty is concentrated. The contradictions of the subsistence sector as a purveyor of cheap labor to the commercial sector of the economy imply population growth and ecological destruction that reinforce rural misery. This theory provides a framework to analyze the political economy of rural development programs. Land reform and small farmer rural development projects are discussed in this context.

Key words: unequal exchange, functional dualism, subsistence agriculture, rural poverty, rural development projects.

Agricultural poverty has generally been analyzed in the context of "traditional" agriculture. Schultz (1964) has defined it as a state of economic equilibrium reached by agriculture over a long period of time and characterized by constant traditional technology and unchanging farmer preferences and motives. In this state farmers have been observed to be poor but efficient in their use of resources.

In this context the origins of agricultural poverty are dissociated from the dynamics of development in other sectors of agriculture, in other economic activities, and in the world economic system. To help farmers escape from the misery of traditional farming, recommendations are for the provision of new technological alternatives. In particular, many have looked to the application of the Green Revolution technologies in small farmer projects as a means of extricating farmers from this low-level equilibrium trap and shifting subsistence peasants to the blessed status of the commercial farmer.

To deal with rural poverty in this context is, in my view, an historical inconsistency that seriously impairs our ability to delineate and interpret the origins and dynamics of poverty and to identify the means by which it can be attacked. The alternative interpretation that is defended in this paper is that underdevelopment cannot be treated apart from development if backward areas or countries are related by the market to the advanced areas or countries. In fact, within the world capitalist system, a theory of underdevelopment and rural poverty needs to be a theory of economic space which can explain how the contradictions of development in certain areas transform, in other areas, traditional societies into underdeveloped ones.

For Latin America—and indeed for most less developed countries that have also been integrated into the world economic system through commercial exchange ever since the beginning of colonization—analysis of rural poverty cannot meaningfully be conducted in the framework of traditional societies. Instead, such analysis should be done against a background of historical events that is dominated by the nature of accumulation in the more developed countries, including the economic destruction of traditional societies through market forces after the first industrial revolution in England, the barriers to industrialization following the second industrial revolution in the twentieth century, the conditions of unequal commercial exchange be-

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tween developed and dependent nations and the consequent need for low wages in the periphery, the exhaustion of import substitution policies to promote industrialization and the transformation of industry into an economic and social enclave in the 1960s, and the resulting reinforcement of structural dualism and marginalization of large sections of society. Because agriculture serves as a natural refuge for marginal populations enabling them to satisfy part of their subsistence needs, rural poverty should be analyzed in the framework of marginality rather than traditional culture.

In this paper the concept of rural marginality will first be defined. Its historical origins in Latin America and its economic rationality will be conceptualized in a consistent model of capital accumulation in the world economic system. This model will then be used to analyze the economic and social significance of alternative approaches to rural development. The purpose here is to construct a taxonomy that can be used to define and evaluate some important aspects of rural development programs. This taxonomy is based on a double dichotomy, that is, the sociopolitical structure of a country is described in terms of the nature of class alliances between traditional landed elites, national industrial capital, and foreign capital, while the sociopolitical nature of rural development programs is characterized as integrative (instruments of social control) or incorporative (instruments of social liberation).

Marginality and Peripheral Capitalist Development

The concepts of periphery and marginality are essential for the construction of a theory of underdevelopment. The periphery is that portion of economic space which is characterized by backward technology with consequent low levels of remuneration of the labor force and/or by advanced technology with little capacity to absorb the mass of the population into the modern sector.[1] These excess human masses created by the very process of economic growth are the "marginals." They can be found in all sectors of the economy and are functionally related to the modern sector that needs them to face the conditions under which growth occurs in the periphery. In agriculture they are the farmers who lose control of the means of production because they cannot withstand the competitive pressure of the modern sector or the farmers who see their economic condition deteriorate as they retain traditional production techniques, but in both cases they cannot sufficiently proletarianize themselves to compensate for the income loss because they cannot be absorbed or fully sustained by the modern sector. Inevitably, they join the ranks of marginals as *minifundistas* and subsistence farmers as do also many of the new entrants into the labor force who cannot find employment in the modern sector.

In contrast to the peripheral economies, the central economies have already had their industrial revolution and are characterized by an intensive rate of capital accumulation and the potential of making full use of their labor force with modern technology. Marginal populations also exist in central economies where they constitute the *lumpen-proletariat,* but the phenomenon there is quantitatively different as they consist principally of dispersed groups of frictionally unemployed (in the process of structural change), of temporarily unemployed (in cyclical phases of economic adjustment), or of unemployables (for physical or psychological reasons). In peripheral economies they constitute large masses who have been objectively created by the dynamics of accumulation (Quijano).

Historically the transformation of Latin America into a periphery of the world capitalist system occurred first through colonization, which integrated the region into the commercial market, and later through efforts, essentially by England, to destroy the Iberian colonial empire in order to establish free trade with the rest of the world. The negative effects of free trade policies became clear during the nineteenth century as they prevented both the development of a national industry behind needed protective tariffs and the rise of a strong national bourgeoisie. Moreover, those policies encouraged the maintenance of economic systems based on the trade of primary products against manufactured consumption goods and hence provided the basis for class alliances between traditional landed elites and British capital to maintain the internal social status quo. Indeed, for the dominat-

[1] The center-periphery concept was first introduced by Raul Prebisch and the Economic Commission for Latin America of the United Nations. This concept has been used to develop a theory of accumulation in peripheral capitalism by Frank, Cardoso, Hinkelammert, Dos Santos, and Amin (1974). For a review of these theories, see Chilcote.

ing classes there is economic rationality to the transformation of Latin American countries into peripheries, for such transformation has enabled them to capture part of the large surplus of the agro-exporter sector and hence to enjoy consumption patterns similar to those of developed countries while retaining all the advantages conferred by their social position in underdeveloped economies (cheap labor services, social power, etc.). Under the agro-exporter model, unequal exchange to the benefit of the center is obtained on a "voluntary" basis by co-opting the traditional elites into sharing in the surpluses extracted. Maintenance of low agricultural wages through precapitalist relations of production, imposed by the elites to tie labor to the land and alienate it from its own opportunity cost on the labor market, produces deterioration of the external terms of trade to the benefit of the center.[2]

With the second industrial revolution in the twentieth century, conditions for industrialization of peripheries have changed drastically. No longer can capital goods be produced using traditional goods, even under high tariff protection; now their production requires modern goods, and these must be imported from the developed countries. Under these conditions, the import capacity of the economy (severely constrained by unequal exchange) has become the bottleneck to industrialization. Through severe market interventions, conscious exclusion of foreign capital, and public assistance to the development of technology, Japan (in the late 1800s) was the last country to transform itself into a developed center. Henceforth, trade protection and the rise of national entrepreneurial classes were not enough to permit development without marginality. Constrained by foreign exchange obstacles to the importation of capital goods, industrial development could not acquire the breadth and dynamics needed to generate enough employment to compensate for the destruction of traditional structures.

Early in the twentieth century, import substitution policies injected a new dynamic into the industrial sector. Industrialization aimed at capturing the existing national market which developed in the process of exchange between exports of primary products and imports of manufactured consumption goods—first for mass consumption items and later for luxury (durable) goods. Soon, nevertheless, and particularly after the 1930s, the terms of trade in the exchange between raw materials and capital goods deteriorated "coercively" against the periphery. This deterioration was caused by systematic market distortions imposed by the center economies in taking advantage of the global monopoly which technological and capital goods dependency of the peripheral nations confers on them.[3] Given a unique world market for capital, the cost of unequal exchange had to be transferred to the only nontradable factor—unskilled labor—and continued industrial development in the periphery is now conditioned by the ability of nations to reduce their labor costs.[4]

Two means can be used to cheapen labor. One is to impose repressive labor policies—an instrument that clearly has been extensively used but is limited by the organization and insurgency potential of the working classes; the other is to lower the cost of those mass consumption items that constitute the bulk of labor's budget and hence are determinant of labor cost. Food, textiles, and popular construction are the producing sectors most negatively affected by the consequent commercial distortions that depress the internal terms of trade against wage goods. As a result, profitable investment ventures are confined to that subset of the industrial sector which is oriented to satisfy demand from the upper classes and is consequently intensive in advanced technology and imported capital goods. As the scope of import substitution expands to include intermediate goods that are more intensive in technological content and capital, the foreign exchange bottleneck becomes more acute, the employment effect is more limited, and the multiplier effect of imports on the value added to national raw materials is reduced. By the 1960s, industry had

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[2] The theory of unequal exchange, based on the causality from cheap labor to deteriorated external terms of trade, was developed by Emmanuel who relaxes the Ricardian and neoclassical assumption of nontradable factors and postulates instead that capital is internationally mobile while labor is not. Market equilibrium thus requires that the rate of return to capital equates in trading countries. Differential wage rates between center and periphery—resulting from precapitalist relations of production in the periphery and superior labor bargaining power in the center—will lead to deteriorated terms of trade against the periphery even if productivity of labor is equal in both areas.

[3] The magnitude of the detrimental effects of these distortions on the peripheral nations is so great that it gave rise to the UNCTAD III meeting in 1972.

[4] The theory of unequal exchange, where causality runs from coercive deterioration of the external terms of trade to low wages in the periphery, has been developed by Braun and Amin (1974).

transformed itself into a large enclave of modernization that was unable to generate enough employment to absorb available labor.

Under conditions of unequal exchange, the effect of import substitution policies has been to replace the initial sectoral linkage (characteristic of peripheries) between the export sector of primary goods and the import sector of luxury-consumption items by a new linkage between the export sector of primary products and the import sector of capital goods for the production of luxury-consumption items (or, in economies that reconvert for outward growth, for the production of exportables). In contrast, in center economies the fundamental sectoral linkage is between the production sector of capital goods and the production sector of mass consumption goods. In this contrasted industrial structure of central and peripheral economies lies the economic rationality of labor incorporation in central economies and of marginality in peripheral areas.

In central economies the distribution of income between capital and labor determines the dynamics of growth. The return to capital conditions accumulation in the capital goods sector: it determines the capacity of the system to produce. The return to labor conditions the size of the market for mass consumption goods: it establishes the capacity of the system to consume. No automatic equilibrium exists between returns to capital and to labor; these are determined by relative forces in the social system.[5] Nevertheless, a necessary relation exists between the two returns for economic growth to proceed. In the continued adjustment process between capacity to consume and to produce, economic fluctuations will result with alternations of inflationary and unemployment crises, but the system will tend toward nearly full employment of its labor force and incorporation of all producing sectors in the modern nucleus of the economy.

In the central economy labor constitutes both a cost and a benefit to capital; it represents a cost as wages are subtracted from profits but also a benefit as wages serve to generate the demand that will allow further accumulation. With increasing monopolization of capital and with organization of labor at the national level, this necessary relation leads to the possibility of a "social contract" between capital and labor under the auspices of the state, which allows real wages to relate effectively to increases in labor productivity (Amin 1972). Economic rationality of this social contract is the basis of the liberal social democrat philosophy in center economies.

The rise of such a social contract is prohibited in peripheral economies by their distinct sector linkage (that between export of primary products and import of capital goods for the production of luxury items).[6] In those economies labor constitutes only a cost to capital and is not simultaneously a benefit, for industrial production is oriented not toward mass consumption but toward consumption by the upper income classes. Higher returns to labor and distributive policies in general (e.g., land reform) would have insignificant market effects for the existing modern industrial sector. In addition, since the capacity to produce is restricted by the foreign exchange bottleneck, the capacity to consume is rarely an effective constraint, as chronic inflationary pressures demonstrate. The dynamics of peripheral accumulation in the context of unequal exchange is based on continued dominance of capital over cheap labor. In fact, it is by this very process of labor's submission to modern capital that societies make the transition from traditional to peripheral.

Just as incorporation of labor is in the center a condition for growth, marginality is in the periphery a contradiction of growth. In the center, distributive policies do not contradict the logic of capital accumulation; in the periphery they do. In fact, especially if rates of economic growth are low, increasing the size of the domestic market for modern industry will require regressive policies to boost the purchasing power of the upper classes. In the center, traditional production structures are incorporated by the modern sector; not so in the periphery where structural dualism will deepen, being a necessary condition for growth of the modern sector.[7]

In sum, a first major contradiction of

[5] This is the central proposition of the Cambridge controversy of capital which dismisses the existence of a unique "just" return to labor and capital given as the solution of a general equilibrium economic system (Harcourt).

[6] Because of differences in income levels, the same durable goods that are mass consumption items in central economies are luxury consumption goods in peripheral economies. The demand for mass consumption items arises primarily from the return to labor while that for luxuries originates mainly from the return to capital.

[7] This shows that the dual economy models of both classical and neoclassical varieties simulate a dynamics of growth that characterizes central economies but is the exact opposite of peripheral development.

capitalist growth in peripheral economies is the structural crisis in the balance of payments that results from capital goods dependency (a consequence of the second industrial revolution) which confers on central economies a global monopolistic privilege and with that the possibility of deterioration of the terms of trade against the periphery. Unequal exchange, in turn, implies the need for reducing labor costs which results in unfavorable terms of trade for wage-good producing sectors and brings about a modern industrial sector confined to the production of luxury goods. Even where outward growth can confer substantial dynamics to the modern industrial enclave, reinforced structural dualism and marginality are the dominant traits of peripheral societies. This contradiction, in turn, implies contradictions within agriculture from which both agricultural stagnation and rural poverty result.

Agricultural Stagnation and Rural Poverty

In most of Latin America, the opportunities for profitable industrial investments, created in the early 1900s by import substitution policies, induced the traditional landed elites to extend their sectoral control toward industry and finance while retaining control of land in the *latifundio*. The reverse movement sometimes also occurred whereby new industrialists sought access to the land in order to diversify portfolios and to gain access to power over the institutions of society. In all cases, agricultural interests were strongly integrated with urban interests and increasingly subject to their dominance (Stavenhagen). Since industrialization requires low wages and overvalued exchange rates to cheapen capital imports, commercial and market distortions result in internal terms of trade that are dramatically unfavorable to agriculture.[8] This condition has been true, especially since the 1930s when collapse of the international market made more pressing the need for national industrialization. Distortions have been greatest in countries like Chile where food production does not participate vitally in the generation of foreign exchange. Except in Mexico, where land reform has eliminated dominance of the traditional elites and opened the way for ambitious infrastructure investments and the diffusion of land-saving technological change, agriculture has entered upon a long period of stagnation. Development of capitalist farming in food crops has been blocked. Only the *latifundios* have been maintained as viable economic units through institutional control by the dominating elites who monopolize institutional services (institutional credit, technology, information, etc.) and derive from them economic compensations for the unfavorable terms of trade. Part of the cost of stagnation has been shifted to labor through miserable wages.

With the rise of rampant marginality, the social relations of production have been gradually redefined from precapitalist (where workers' subsistence plots are located within the *latifundio*) to a functional dualism between commercial sector and *minifundio* (where the subsistence sector is now external to a capitalist agricultural sector). Precapitalist relations are needed to cheapen labor by tying it to the land and alienating it from its own opportunity cost as long as it is a scarce factor, a situation characteristic of most of Latin America until the 1950s. Once marginality is widespread, labor costs can be further reduced by making use of wage labor instead of labor partially paid in land privileges since that permits landlords to recover the land previously given to workers and to tailor the hiring of labor to fluctuating seasonal and annual needs.

In the central economy, proletarianization of labor in the process of the development of capitalism is due to two economic motives: the desire to reduce labor costs which is accomplished by paying labor only for time actually worked (in contrast to enslaved or servile labor whose subsistence must be covered even in periods of sickness or slack in labor needs) and the need to expand the market for consumption goods in order to permit continued accumulation. Market expansion requires destruction of the subsistence economy and redistributive policies toward labor. Because of the fundamental asymmetry between central and peripheral economies in the role of labor in market expansion, the first motive fully applies in the periphery, but the second does not. As a result, labor costs in the periphery can be further reduced by maintaining the subsistence economy since that provides the commercial sector with labor whose

[8] Schultz (1968, pp. 175–84) refers to these distortions as "cheap food policies" and attributes to them major responsibility in inducing agricultural output stagnation.

subsistence is already partially covered by production in the *minifundio*. Labor wages can thus be collapsed below the subsistence needs of the worker and his family by an amount equal to the net value of production in the subsistence sector. Development of a functional dualism between subsistence agriculture and the commercial sector is fully consistent with the needs for growth in the periphery under conditions of unequal exchange. In this structure the subsistence sector produces cheap labor for the commercial sector which, in turn, can produce cheap food for the market.

This role of the subsistence sector as a producer of cheap labor implies a specific division of labor by sex and age in the *minifundio*. While men largely do wage work outside the *minifundio*, women and children are the essential productive agents. Dramatic contrasts also exist at this level between center and periphery. In the center, women essentially have a consumption function (vividly described by Galbraith, chapter 4), while in the subsistence sector of the periphery, women's function is in production. In the center, children are primarily consumption factors (a rationale that is central to the demographic analyses of the Chicago School [Leibenstein, pp. 457–79]), whereas in the subsistence sector of the periphery, they are production and protection agents. The pressure of poverty in the *minifundio* implies the need to search for additional productive resources. Strict individual economic rationality in the subsistence sector will often lead to mining the land and increasing family size in order to face poverty, and poverty thus leads to more poverty.

Generalized rural poverty in rural Latin America is hence the logical outcome of a three-level chain of exploitative relations. First is the international level between dominant centers and dependent peripheries in the context of unequal exchange between raw materials and industrial capital goods. Second is the sectoral level between modern industry, which produces commodities for the upper classes and the external market, and the sectors which produce mass consumption items in the context of the need for cheap wages and the consequent deterioration of the internal terms of trade. Third is the social level between landlords and agricultural labor and marginal populations in the context of transmission to labor of the costs of international and sectoral level unequal exchange as well as exclusion of the mass of population from modern sector employment. Only when the food sector is itself a major component of the export sector is this chain reduced to a two-level set of relations, as unequal international exchange is brought to bear directly on the terms of trade for agriculture which will then be generally more advantageous (as in Argentina and Uruguay) and rural poverty somewhat less acute.

To these three levels of exploitative relations correspond specific contradictions that jeopardize economic growth and social stability in the periphery. At the international level, the structural deficit in the balance of payments blocks expansion of the modern industrial enclave. At the sectoral level, agricultural stagnation raises labor costs, unleashes inflationary pressures, and worsens the balance-of-payments deficit. At the social level, miserable wages build up revolutionary pressures that are reinforced by ecological and demographic contradictions in the subsistence sector.

In the context of these fundamental contractions of growth in the periphery, it is clear that rural development programs do not have (in the rationality of capital accumulation) redistributive goals dictated by the economic need of increasing market size for the modern industrial sector. Land reform programs generally pursue two simultaneous objectives (dictated by these contradictions) whose relative importance is determined by particular historical circumstances: a production goal designed to alleviate deficits in the balance of payments and to cheapen wages and a distributive goal, which is fundamentally political, designed to promote social integration of the potentially revolutionary strata of the peasantry and their eventual incorporation into social groups that will favor maintenance of the social status quo.

In Chile the land reform of the Christian Democracy aimed at increasing production in the nonreformed agricultural sector through modernizing changes and through threats of expropriation, while the *asentamiento* was used as a political instrument of social control.[9] While a small number of benefited farmers were largely incorporated in the Christian Democracy, the frustrated non-

[9] This makes it similar to the design of the Mexican land reform where strong output growth is sought in the commercial sector and social control in the *ejido* (Gutelman).

beneficiaries of the reform (whose political power had been increased by the important unionization movement that enlisted five times more members than beneficiaries of the land reform) joined the opposition forces. Simultaneously, the traditional elites, displeased by the economic cost of social reforms and the threats they represented to property in other sectors of the economy and to political stability, broke away from the Christian Democracy and presented their own presidential candidate in the 1970 elections, dangerously dividing the liberal and conservative forces. Frustrations of both excluded peasants and traditional elites with the land reform were determinant factors in the election of a socialist regime (Barraclough).

The concepts of integration and incorporation are useful to characterize the scope of processes of social change (Lehmann). Integration is a process that comes from above, promoted by more powerful groups in favor of less powerful ones and by which the latter are provided with new channels of relation with the central institutions of society. Integration can be obtained either by restructuring the nucleus of the incorporated so that part of their power, income, or assets can be offered to the marginals or by organization of the marginated so that they gain access to social institutions. It does not necessarily imply structural or social change but aims only at improving the relations between nonincorporated and incorporated groups. Incorporation, in contrast, is a process that develops from the bottom upward (although it may be initially induced from above) through which a social group acquires "rights of citizenship," rights which it then may use to enforce its own claims against other incorporated social groups. In different historical and social contexts, these rights will be used for different specific purposes.

It has been argued that, to understand rural poverty in most of Latin America, the concept of traditional agriculture needs to be replaced by that of functional marginality. To this end, the elements of a theory of marginality as an integral part of the dynamics of growth in peripheral economies of the world capitalist system have been outlined. This theory permits identification of the variables that affect rural poverty and understanding of the political economy of alternative strategies aimed at alleviating it.

Political Economy of Rural Development Projects

In addition to land reform programs, integral and partial rural development projects have been frequently used in recent years as strategies to improve the economic conditions of subsistence farmers (Mosher; Adams and Coward).[10] These projects are largely in the tradition of community development programs but seek new vitality in capitalizing upon the power of social change imbedded in the technology of the Green Revolution. Since, in almost all cases, subsistence farmers are marginals rather than "forgotten" or "accidental" traditional social sectors, poverty has an economic rationality within the broad economic system. Therefore, rural development projects, both in design and evaluation, will have to be consistent with this rationality.

Rural development projects, oriented at subsistence agriculture, differ in their goals from land reform programs. The production objective will be set not in terms of national necessities (improving the balance of payments and lowering food prices) but of the consumption and income levels of the marginal sector concerned. Hence, rural development projects will be of no major avail in relieving the structural deficit in the balance of payments or the aggregate output stagnation. Instead, they will have the political goal of alleviating rural poverty in order to contain the popular pressures brought about by increasing marginality and/or the economic goal of cheapening labor from the *minifundio* by increasing the share of its subsistence needs covered through subsistence agricultural production. But such projects may also be a part of broader processes of social change aimed at breaking away from the three-level chain of exploitative relations previously identified.

To describe the political economy of rural development projects, it is useful to introduce a taxonomy among social formations based on the nature of the alliances between traditional landed elites, national industrial capital, and foreign capital. The nature of these alliances

[10] Mosher refers to "integrated" versus "nonintegrated" projects to contrast projects that simultaneously provide a number of services or activities for small farmers located in a specific geographic region with those that offer only a limited number of services or activities. Since the concept of integration has a different meaning in this paper, these projects shall be referred to as "integral" versus "partial" instead of according to Mosher's terminology.

permits contrasting three prevalent contexts within which rural development projects may occur in Latin America.

First is the situation in which the alliance between traditional landed elites and industrial capital and that between industrial capital and foreign capital remain intact. Belonging in this category are northeast Brazil, Argentina, and Uruguay, none of which has had any significant land reforms. In these areas land tenure is largely characterized by the *latifundio-minifundio* dualism, and traditional landed elites dominate the institutional process. Food production is stagnant because of the compound influence of unfavorable terms of trade and of the supply to agriculture of institutional services that are conditioned by the traditional elite's objective of social status quo and are, therefore, not oriented to land-saving technological change. As explained before, the internal terms of trade are severely affected by unequal international exchange, and the less agriculture participates in the generation of foreign exchange earnings, the more unfavorable these will be. Since monopolization of institutional services (credit, technology, information, etc.) by the traditional elites is essential for them to derive economic compensations from the unfavorable terms of trade and to sustain the profitability of the *latifundio,* their continued dominance over the institutions is an economic imperative. The dilemma for them is hence one of deriving maximum benefit from institutional services while simultaneously managing the institutional process in such a fashion that reproduction of institutional control is also assured. Since monopoly of the land is the basis of the social power of these elites, they will foster only those changes in technology that are not a substitute for land. This will orient the technological path toward mechanical, labor-saving, and generally non-yield-increasing technologies instead of toward biochemical land-saving technologies of the Green Revolution type (de Janvry). Even if the rate of technological change is intense, the social status quo constraint imposed by the traditional elites will bias technology and largely destroy the output growth potential of technological progress.

Under prevalence of this double alliance, food output stagnation and rural poverty through transfer to labor of the cost of stagnation will result. Marginality becomes widespread because the modern industrial sector cannot absorb the mass of labor in spite of eventual high rates of growth. Rural development projects in the *latifundio-minifundio* structure are precluded when the *minifundio* is captive within the *latifundio* under pre-capitalist relations of production. For external *minifundios,* rural development projects probably can be only limited in scope and oriented toward integrating marginal farmers enough to alleviate social pressures but without risking incorporation. The magnitude of rural development projects will be restricted by their high economic cost for the dominating class. At this stage of social organization, land reform and other programs oriented toward giving some institutional control to the potentially productive social sectors of agriculture are probably prerequisites to rural development projects.

Once land reform programs break through the alliance between national industrial capital and traditional agrarian classes, the conditions may be set for more meaningful rural development projects as, for example, in Mexico. While unfavorable terms of trade for food production remain as an effect of unequal exchange, institutional control has now accrued to rural and urban capitalists, and output growth can be given impetus by land-saving technological change and infrastructure investments. The social tensions in the countryside, generated by industrial and rural marginality, are transitorily frozen in a contrived dualism. But combined demographic pressures and contradictions on the distribution of income, brought about by peripheral accumulation, soon aggravate marginality and social stress.

Under these conditions, rural development projects will tend to be aimed at prolonging the social status quo of contrived dualism. Therefore, at least initially, such projects will be integrative instruments of social control over the rural marginals. But marginals can gain true access to sustained social gains only if projects evolve from integrative to incorporative. In some instances, rare because of the political risk involved, projects may be deliberately oriented toward promoting social incorporation in order to attempt capturing the political support of the newly incorporated. In other instances, the successful maturation of projects may lead them to evolve spontaneously from integrative to incorporative as a

result of increasing contradictions between complexity of the production process and exogenous decision making. Creation of credit groups, cooperatives, etc., can be effective inducement mechanisms of this transition.[11] Technological change can then become a powerful means of inducing social change rather than an end in itself. It can permit marginals to become conscious—through perception of the economic gains that can be derived from it—of the need to organize and of the possibility of thus gaining their due share of access to and control over the institutions of society. Here an analogy exists between proletarians and marginal peasants: for proletarians wage increase (income increase) is the initial perceived want, and unionization (institutional power) is the instrument toward attaining this goal; for marginal peasants technological change (income increase) is the initial perceived want and solidarity groups (institutional power) the instrument. In both cases the long-run valid outcome is social change, based on the rise of institutional power for the working and marginal classes. Wage and technological changes are only instruments of social polarization.

The design of successful rural development projects requires a clear understanding of the process by which rural poverty is created and perpetutated. Specifically, the mechanisms by which economic surpluses are extracted from the subsistence sector and the socioeconomic reactive process to poverty within the subsistence economy need to be clearly identified, since these determine both the diffusion of program recommendations and the ultimate social distribution of welfare gains from such a program. A particular determinant is the adjustment of outside wages received by workers from the *minifundio* when resource productivity increases in the subsistence sector have been brought about by rural development projects. While productivity increases may make it possible for those *minifundistas* who have enough productive resources to progress from semiproletarian workers to family farmers, most of them will still have to compete for outside wage work. If this competition is intense, wages may eventually collapse by an amount equal to the increase in net income in the *minifundio*, in which case the welfare gains from rural development projects would be extracted from the subsistence sector to the benefit of the employing sector. A welfare program for the rural poor could thus result in a subsidy to the commercial sector. Only by careful design of complementary institutional and structural changes will welfare gains possibly be retained by the subsistence sector.

A third situation exists when the double alliance between traditional landed elites, national industrial capital, and foreign capital has been broken down as in the "new Latin American nationalism" of Peru or the socialist rationality of Cuba. Here, as the influence of unequal exchange on the industrial structure is presumably eliminated, the stage is set for planned autocentered agricultural and industrial development. Industrial production can be oriented toward mass consumption items, and redistributive policies acquire logic in terms of market expansion. As in central economies, the social management of a balance between capacity of the system to produce and to consume becomes a necessary condition for growth. Terms of trade for agriculture as well as institutional processes aimed at land-saving technological change and at infrastructure investment can be managed consistently. And rural development projects can be used as powerful instruments of social incorporation. Nevertheless, potentials and achievements remain far apart in the actual transitional phases. Dependency from one ideological block tends to be replaced by dependency from another, and integrative rural development tends to be preferred over incorporative for the sake of social control.

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[11] The "solidarity groups" in Plan Puebla through which group credit is obtained are an example.

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Notes

Revisiting the Dorfman-Steiner Static Advertising Theorem: An Application to the Processed Grapefruit Industry

Ronald W. Ward

Dorfman and Steiner's article in the early 1950s set forth the theorem that "a firm which can influence the demand for its product by advertising will, in order to maximize its profits, choose the advertising budget and price such that the increase in gross revenue resulting from a one dollar increase in advertising expenditures is equal to the ordinary elasticity of demand for the firm's product"(p. 826). This theorem has similar implications for an industry when in fact the industry can influence the total level of advertising. In particular, the theorem provides an additional policy tool for many commodity markets where the producers of the commodity support a generic-type advertising program.

The simplicity of the Dorfman and Steiner theorem is appealing; however, its empirical counterpart is often difficult to generate due to the complexity of measuring advertising effectiveness. This paper will, however, present an application of the theorem where the simplicity of the Dorfman-Steiner demand model is representative of the industry studied. Specifically, an empirical measure of the effectiveness of generic advertising of canned, single-strength grapefruit juice (CSSGJ) is presented (Ward). The model is useful for evaluating alternative advertising levels when the commodity price can and cannot be influenced by aggregate industry pricing strategies.

Two policy questions of primary concern to the processed grapefruit industry relate to what the effects of the overall generic advertising program have been and what gains could be realized if better coordination of advertising and pricing were possible. The Dorfman-Steiner theorem is relevant for addressing these questions.

A review of the Dorfman-Steiner theorem will be presented in the first section followed by a description of the marketing system for CSSGJ. An application of the theorem and its implication for the grapefruit industry are discussed in the last two sections.*

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Dorfman-Steiner Theorem

The demand for product q is influenced by both the price of the product p and the intensity of the advertising effort a giving

$$q = D(p, a). \tag{1}$$

Assuming that q, p, and a are measured at the same level in a vertical market structure, then a change in q follows where

$$dq = D_p\, dp + D_a\, da, \tag{2}$$

letting $D_p = \frac{\partial D}{\partial p}$, $D_a = \frac{\partial D}{\partial a}$.

For each feasible level of q, there exists a locus of coordinates (p, a) such that $dq = 0$. Thus,

$$dp = -\frac{D_a}{D_p}\, da. \tag{3}$$

Within this locus there further exists a set of coordinates such that $(pq - a)$ is maximized. Dorfman and Steiner set forth the necessary condition for net revenue maximization for any given q as

$$\begin{aligned} qdp - da &= -\left(q\frac{D_a}{D_p} + 1\right)da \\ &= 0. \end{aligned} \tag{4}$$

Then a positive value of a cannot be optimal for a given q unless the value within the parentheses in equation (4) is zero. Defining the elasticity of demand as $\epsilon = D_p(p/q)$, the marginal value product of advertising as $\nu = D_a p$ and substituting both ν and ϵ into equation (4), profits to an industry for any given q are maximized when

$$\nu = -\epsilon. \tag{5}$$

CSSGJ Model

Processed grapefruit pricing and advertising decisions are initially determined at the FOB level. The FOB price is an administered price usually set by the larger processors exerting considerable price leadership.[1] In contrast, most of the grapefruit ad-

[1] Pricing policies are generally established by various processors in the state in accordance with their target sales objectives

vertising is generic in form and is under the direct control of the industry through the Florida Citrus Commission. The commission, acting through the Florida Department of Citrus, regulates the amount of advertising as well as the general theme of all commercials. However, the commission cannot regulate prices.

Advertising reaches the consumer directly while the effects of FOB pricing policies are realized through the retail-FOB price relationship

$$p = H(p_f), \tag{6}$$

where p = average annual retail price per gallon of canned grapefruit juice and p_f = average annual FOB price per gallon of canned grapefruit juice. Consumption responses to both pricing and advertising are measured at the retail level as initially expressed with equation (1). Finally, FOB sales q_f are some function of the retail sales

$$q_f = K(q), \tag{7}$$

where q = annual retail gallons of canned grapefruit juice (million gal.),[2] q_f = annual FOB gallons of canned grapefruit juice (million gal.), and a = annual advertising expenditures ($ million). Since the advertising decisions are funded at the FOB level, the pricing and advertising strategy using the Dorfman-Steiner theorem follows where

$$q_f dp_f - da = 0. \tag{8}$$

Using equations (2) through (5), the necessary condition for defining coordinates to satisfy equation (8) is that $\nu_f = -\epsilon_f$, assuming both the marginal value of advertising and the elasticity of demand are now derived at the FOB level.

taking into account their expected ending inventories. Frequently, price adjustments are evident when there appears to be a redistribution of market shares among the firms. The concept of administered pricing denotes a method of arriving at or determining a price. It should not be used to imply undesirable price behavior.

[2] FOB sales q_f will exceed total retail sales q because q_f includes some institutional purchases that cannot be netted out of q_f. However, the movements in q and q_f are highly related as shown in table 1.

The explicit counterparts to equations (1), (6), and (7) follow and the estimates are reported in table 1:

$$q = \beta_0 + \beta_1 p + \beta_2 \frac{1}{a}, \tag{9}$$

$$p = \alpha_0 + \alpha_1 p_f, \tag{10}$$

and

$$q_f = \tau_0 + \tau_1 q. \tag{11}$$

Using these explicit equations, ν_f and ϵ_f are derived as

$$\nu_f = -\tau_1\beta_2\left(-\frac{p_f}{a^2}\right), \tag{12}$$

and

$$\epsilon_f = \tau_1\beta_1\alpha_1\left(\frac{p_f}{q_f}\right). \tag{13}$$

Table 2 compares the actual to the estimated values for the dependent variables included in table 1, and table 3 presents alternative structural equations for equation (9).

Competitive versus Coordinated Pricing

Using the Dorfman-Steiner theorem results, it is relatively easy to show the coordinates of a and p_f for some given value of q_f, say q_f^0. The value of q_f^0 is particularly relevant to the grapefruit industry in that price adjustments are generally made in order to achieve a given target value of sales. The target value is derived from firms' review of supply and potential carry-over positions. Letting q_f^0 be the target value, then from the Dorfman-Steiner theorem where $\nu_f = -\epsilon_f$ it follows that an advertising level a^0 will be desirable when

$$a^0 = \sqrt{\frac{\beta_2}{\beta_1\alpha_1}\, q_f^0} \tag{14}$$

or

$$a^0 = 0.886\sqrt{q_f^0}$$

Table 1. OLS Estimates of the CSSGJ Demand and Margin Equations

	Estimated Coefficients for the Variables[a]							
Equation	p_f	p	$\frac{1}{a}$	q	Constant	R^2	DW	n[b]
(9) q	—	−10.15 (−2.35)	−5.34 (−8.79)	—	69.82 (11.70)	0.961	1.67	7
(10) p	0.671 (8.851)	—	—	—	0.648 (8.641)	0.975	0.92	4[c]
(11) q_f	—	—	—	1.25 (5.239)	−0.172 (−0.015)	0.846	1.45	7

[a] Value in parentheses is the t-statistic.

[b] The number of observations in time-series advertising data is generally short because the nature of the advertising copy will change over long time periods. This analysis was based on the periods 1966–67 through 1972–73 because the advertising copy and media used were known to be relatively constant during these years. Funds allocated to a are related to total crop and not to sales in the same period. Hence, there is no reason to expect simultaneity between q and a.

[c] The degrees of freedom for equation (10) were less than for the other equations because reliable estimates of the FOB price prior to 1969–70 were not reported.

Table 2. Estimated and Actual Values of Variables Used for the Models Shown in Table 1

Season	p	$\hat{p}$[a]	p_f	$\hat{q}$[b]	q	$\hat{q}_f$[c]	q_f	a
	$/gal.			million gal.				$ million
1972–73	1.294	1.287	0.953	53.52	53.77	65.59	66.68	1.837
1971–72	1.344	1.345	1.039	51.34	51.11	64.35	63.96	1.053
1970–71	1.332	1.333	1.020	49.31	50.40	65.02	61.43	0.905
1969–70	1.274	1.279	0.941	45.93	45.33	61.13	57.20	0.462
1968–69	1.056	—[a]	—	51.65	49.83	61.80	64.35	0.576
1967–68	1.102	—	—	38.26	38.09	46.74	47.62	0.260
1966–67	0.930	—	—	44.29	45.67	52.27	55.16	0.363

[a] Weighted FOB prices for canned grapefruit were not available for the periods prior to 1969–70. Hence, the relationship in equation (10) was estimated based on $n = 4$.
[b] Retail gallons were estimated with equation (9), table 1.
[c] FOB gallons were estimated with equation (11), table 1.

Given q_f^0 and a^0, the price coordinate (p_f^0) can be immediately derived.

In contrast to the solution where prices can be coordinated along with advertising implicit with the Dorfman-Steiner theorem, the situation where prices and advertising decisions are determined independently is of interest. In particular, given that the FOB price is predetermined either through price leadership by the larger processors or through competitive bidding, then the advertising decision is made according to a quantitative understanding of the marginal value of the program. Using this criterion, a can be increased as long as $\nu_f > 1$. An advertising level (a^*) under the condition that p_f cannot be coordinated by the industry follows when $\nu_f = 1$. Thus,

$$(15) \qquad a^* = \sqrt{-\tau_1 \beta_2 p_f}$$

or

$$= 2.583 \sqrt{p_f}.$$

Intuitively, equation (15) reveals the maximum advertising level that should follow if the industry allocates its advertising dollars according to the knowledge of ν_f only. Likewise, the quantity q_f^0 is now known since both p_f and a^* are given. Alternatively, the Dorfman-Steiner theorem states that for any q_f (and specifically, q_f^0) p_f and a can be coordinated to yield equivalent or greater returns for the same level of sales q_f^0.

Table 3. Alternative Structural Equations for Equation (9)

	t-statistic			
D	p	a	R^2	DW
Linear	−0.038	1.93	0.59	2.69
Exponential	−0.007	1.80	0.56	2.70
Double-log	−0.902	3.57	0.80	1.98
Semilog	−0.964	3.83	0.82	1.96
Reciprocal	−2.353	−8.79	0.96	1.67

Implications of the Dorfman-Steiner Theorem for CSSGJ

The relationship among price, advertising, and sales is shown in figure 1. Curves cc and $c'c'$ show the advertising-price coordinates derived from $\nu_f = -\epsilon_f$ and $\nu_f = 1$, respectively. Product movements are shown with curves mm and $m'm'$, and the industry net gain in revenue from coordinating prices and advertising versus noncoordination is illustrated with curve rr. Specifically, rr gives the revenue difference realized when some target sales level q_f^0 is achieved with the Dorfman-Steiner criteria versus the noncoordination solution.

Suppose that the competitive FOB price is $1.50 per gallon; then the results from figure 1 show that the industry should spend approximately $3.1 million annually on advertising. This would give total FOB sales of 64 million gallons and a net return of $93 million.

The level of a depends on the noncoordinated price p_f where for each 10% change in the FOB price, the level a^* should be changed by 5%. This result provides a very useful index for establishing advertising policy. Considerable time is required to develop and finance advertising programs. Hence, some knowledge of the expected range of values of p_f is desirable in order to approximate the level of a^*. For the example above, if at the planning stage the administered price was expected to be $1.50 plus or minus 10%, the plans for advertising commitments in the range of $2.9 to $3.2 million can be implemented. The sensitivity of a^* to change in the FOB price is evident from $c'c'$, figure 1.

Suppose now the grapefruit industry can influence directly and coordinate the price of its product along with the advertising effort. For the same movements q_f^0 realized above, the Dorfman-Steiner theorem indicates that net returns can be increased by raising both the price and advertising effort. Net returns would increase as shown by point u on rr or by approximately $4.7 million. The coordinates along cc give the values of p_f and a that satisfy the Dorfman-Steiner theorem.

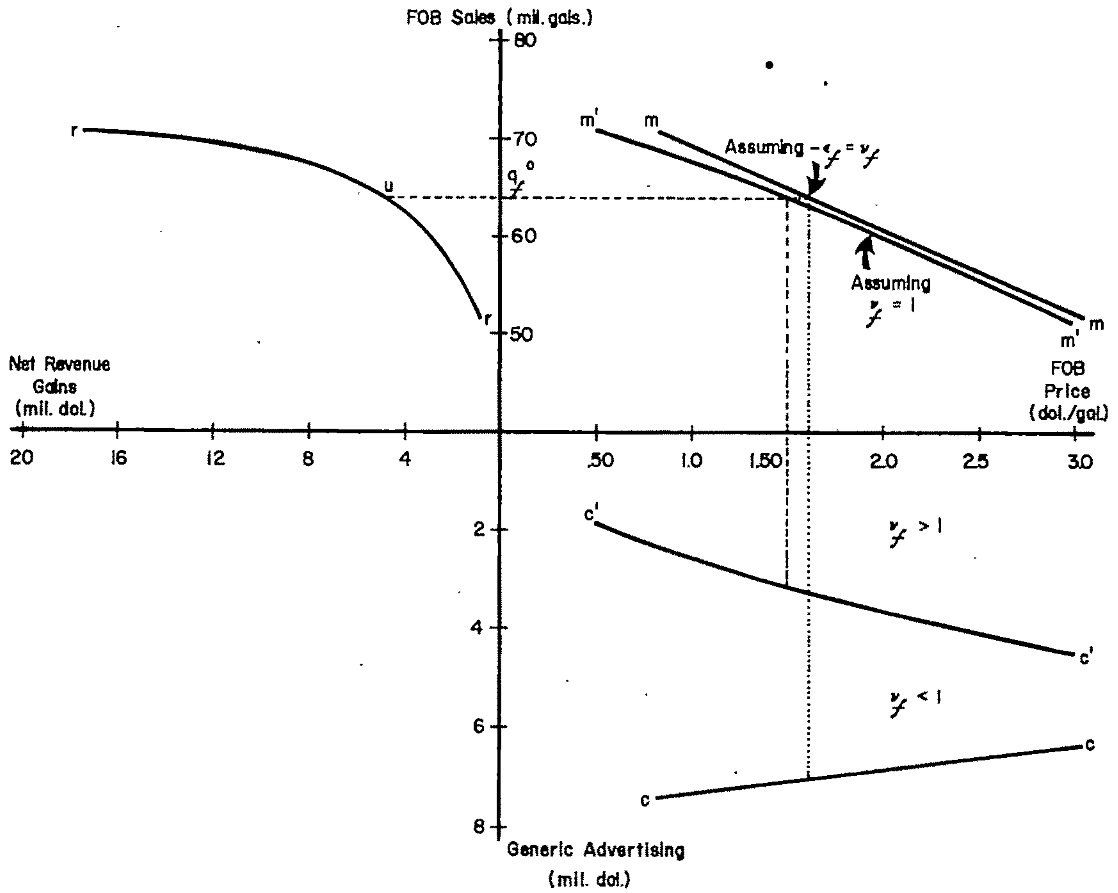

Figure 1. Canned, single-strength grapefruit juice price and advertising coordinates as determined with the Dorfman-Steiner theorem versus ν

The use of the Dorfman-Steiner theorem is particularly interesting for the grapefruit industry in that to move any quantity q_f^0, profits can be increased by increasing advertising even though $\nu_f < 1$. This follows due to the highly inelastic nature of the demand for CSSGJ. The marginal gains from a price increase can more than offset the fact that the marginal value of advertising is less than one. However, the gains from the additional effort are small relative to total sales and such gains decrease rapidly for the higher prices. This is evident from the sharp convexity of curve *rr* for lower q_f values. The magnitude of this gain should give the decision maker useful guidelines for deciding whether changes in the structure, marketing programs, taxing policies, etc., in the industry would be warranted. In particular, additional advertising taxes may be needed to fund increased advertising expenditures. Also, the mechanism to influence price would need implementing.

The question of reductions in the target sales through price increases has not been addressed. Demand is inelastic ($\epsilon < 1$) over the price range shown in figure 1; thus, revenues would increase with price increases. However, inventories would also increase given the historic supply patterns. As suggested in note 1, manageable inventories tend to be one of the industry's primary concerns. This is particularly so since the crop outlook for the next few years suggests that supplies will grow faster than demand. Hence, reduction in target sales levels q_f^0 would continue to add greater inventory burdens.

Conclusion

For many industries, the Dorfman-Steiner theorem provides an appealing way of evaluating the market potential that can be realized through the coordination of advertising and prices. The theorem has special significance for commodity advertising since there have been increased efforts to advertise commodities generically. Yet, prices are determined in the competitive market place for most commodities. The use of federal and state marketing orders provides a means for an industry to influence the price of its products even though the basic industry structure is competitive or oligopolistic.

For the grapefruit industry, the gains from

advertising-pricing coordination must be evaluated against the social and political cost from larger taxes and increased controls. The measured advertising response further suggests the need for improvements in the quality of advertising in order to more effectively influence CSSGJ demand. The problem of the optimal inventories given both stochastic demand and supplies needs to be addressed in additional studies.

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Producer Returns from Increased Milk Advertising

Stanley R. Thompson and Doyle A. Eiler

Each year many agricultural commodity groups spend millions of dollars advertising and promoting generic products. However, empirical analyses of particular generic promotion ventures are scarce (Clement, Henderson, and Eley; Hochman, Regev, and Ward; Nerlove and Waugh).

Advertising and promotional monies are often obtained from producers on a voluntary contribution basis, but a major criticism of voluntary programs is that in an atomistic industry the individual producer has little incentive to advertise since his particular share of the increased commodity demand is small. A major argument for mandatory participation is that of equity; however, little economic evidence is available to address the potential profitability of such expanded programs. Since market experimentation is costly, the historical promotional experience of a particular commodity group can provide an important economic input for use by other producers contemplating expanding their own advertising programs.

For many years New York State dairy producers have voluntarily contributed to advertise and promote the generic product milk. Prior to May 1972; about 60% of the producers were voluntarily contributing at the rate of 3¢ per hundredweight. In May 1972, a New York State Dairy Promotion Order became effective with a mandatory assessment rate of 5¢ per hundredweight levied on milk produced in the state. The voluntary contributions generated about $1.5 million annually compared to some $4 million available annually after the implementation of the Dairy Promotion Order.

With the additional funds, several types of milk promotion activities were expanded. This paper focuses on the program area which has experienced the greatest funding increase—media advertising. Specifically, this paper assesses the effect on producer returns, by market, of the expanded fluid milk advertising effort made possible under the New York State Dairy Promotion Order. The selected model is reviewed, an interpretation of the estimated coefficients is presented, and, finally, an estimate of the returns to producers is presented followed by some implications of the analysis.

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Methodology

The total impact of a given advertising expenditure on milk sales may not be realized immediately but instead may be distributed over time,[1] and the availability of time-series data permits the application of distributed lag models to obtain estimates of both the short- and long-run effects of advertising on sales.[2] In past studies, the long-run effect of advertising on sales was often approximated by the use of a geometric form lag model. This model may not be critically restrictive when annual or even quarterly data are used; however, when monthly data are available the assumption that the largest response occurs at the beginning of the adjustment period is more likely to be violated (see Griliches, p. 24). Previous empirical research has shown that the use of monthly or quarterly data has generated lag structures inconsistent with the Koyck model (Bass and Clarke; Chen, Courtney, and Schmitz).

A polynomial lag model can be estimated without many of the statistical shortcomings inherent in the geometric lag specification (Thompson and Mount). In addition, a polynomial model allows for considerable flexibility in the shape of the lag structure. Therefore, the polynomial lag model was used to examine the effect of advertising on milk sales. The estimation problems and procedures for polynomial lag models are covered in Dhrymes; Johnston; Thompson and Mount.

In addition to advertising, many factors influence the sales of fluid milk such as the traditional decline in milk consumption during the summer months, consumer resistance to higher milk prices, the gradual growth in milk consumption as consumer purchasing power grows, and increased consumption associated with population growth. Although these factors are important in influencing milk sales, the dairyman maintains little control over them. However, he does maintain some control over the amount of money he contributes to milk advertising and promotion programs. In other

[1] The distribution of the lagged effects of advertising can be characterized by the notion of the advertising decay curve. Waugh (pp. 365–70) has explored the theoretical nature of the decay curve and its applicability to economic research designed to evaluate advertising and promotion programs.

[2] In many situations the use of time-series data in the estimation of the relationship between advertising and sales has the problem of simultaneity (Schmalensee). But in New York State, direct consumer advertising expenditures are not determined by the level of fluid milk sales.

words, advertising expenditure is a policy argument in the fluid milk demand function.

Separate polynomial lag models were estimated using monthly price, income, and advertising data from the New York City, Albany, and Syracuse Standard Metropolitan Statistical Areas (SMSA). Milk sales data within each SMSA were obtained from the New York State Department of Agriculture and Markets. Monthly observations from January 1971 to March 1974 included sixteen months of data prior to the expanded promotion effort and twenty-three months after the implementation of the Order.

The following polynomial lag model was estimated:[3]

$$S_t = \alpha + \sum_{j=1}^{11} \beta_j Z_{tj} + \delta I_t + \lambda P_t + \sum_{m=0}^{M} \Theta_m \left\{ \sum_{i=0}^{N} \left[i^m A_{t-i} \right] \right\} + e_t,$$

where $t = 1, 2 \ldots 39$ (January 1971 to March 1974), N = specified finite lag length, M = degree of polynomial, S = per capita daily milk sales in ounces adjusted for the type of days in the month, i.e., number of Sundays, Mondays, etc. (Schenkler and Christ, pp. 28–30), A = deflated actual per capita monthly media advertising expenditures in dollars,[4] Z = eleven zero-one dummy seasonality variables with December as the base class, I = deflated (by CPI, 1967 = 100) per capita annual personal income in dollars, and P = deflated (by CPI) retail price in dollars of whole fluid milk in paper half gallons.

Two decisions to be made in estimating the polynomial lag model are determination of the length of the lag structure (N) and selection of the degrees of polynomial (M). To obtain an indication of the appropriate degree of the polynomial, alternative specifications were estimated. The second-degree polynomial has relatively little multicollinearity for these data while exhibiting adequate flexibility in terms of the form of the lag.

The length of the lag structure considered most representative of the data was obtained by comparing the results of various polynomial specifications estimated with different lag lengths. In these specifications the lagged effects of advertising were positive during and immediately following the initial advertising expenditure and then, at a later point, became negative with corresponding t-ratios less than two. Since theory suggests that the effect of advertising on sales is positive, the length of the lag structure was constrained to equal zero at or near the first detected negative and statistically small influence.

Estimated Coefficients

The estimated coefficients of the eleven zero-one dummy variables assess the seasonal variation of milk sales relative to sales in December, the base month (table 1). The signs of the seasonality parameters indicate the direction of the shift in milk sales among the months of the year, and in general, these results are consistent with other seasonal indexes of fluid milk sales (e.g., Schenkler and Christ, pp. 28–30). For example, the per capita milk sales for July in New York City are 0.88 ounce per day less than they would be in December, *ceteris paribus*. The other monthly coefficients receive a similar interpretation.

Interpretation of the price coefficient in New York City reveals that a 1¢ per half gallon increase in the real price of milk would be expected to decrease per capita milk sales by 0.03 ounce per day, *ceteris paribus*, and the estimated own-price elasticity of demand is −0.185. A $1 increase in real annual per capita income is estimated as increasing per capita fluid milk sales in New York City by 0.0006 ounce per day. Accordingly, the estimated income elasticity of demand for fluid milk is 0.285. Analogous interpretations of the price and income coefficients can be made for the Albany and Syracuse markets (table 1).

The estimated coefficients of the advertising lag structure portray the impact of milk advertising on sales over time. In New York City, the effect of advertising is spread over six months, and the greatest impact of advertising does not occur until two months after the initial expenditure. In Albany and Syracuse, however, the advertising effect dissipated more rapidly and the greatest impact occurred in the month of expenditure. Little confidence can be ascribed to these latter two structural estimates given the precision of their estimated long-run coefficients. The sum of the monthly advertising coefficients show the total response or long-run effect of the advertising expenditure.

The estimated long-run effects of advertising on fluid milk sales show that a 0.1¢ increase in current per capita monthly advertising yields a total increase in milk sales of 1.93, 0.94, and 0.27 ounces per capita for the New York City, Albany, and Syracuse markets respectively, *ceteris paribus*.[5]

[3] The estimation equation is the general distributed lag model after restricting the lagged parameters to follow a polynomial relationship over some finite time period. This polynomial lag structure is defined in terms of a Lagrangian interpolation polynomial (e.g., Johnston, pp. 296–97).

[4] The advertising data represent actual invoiced expenditures. Per capita advertising figures are obtained by dividing actual advertising expenditures in a market by the estimated population of that market's media coverage area. These are then deflated by an index of the cost of prime time spot television.

[5] In New York City, for example, assuming that advertising is increased in a single month by $0.001, that the approximate 1974 cost-of-media-deflation index is 1.34, that the long-run advertising coefficient is 86.2693, and that a month equals 30 days, then $0.001/1.34 = 0.000746 real increase in advertising expenditure, (0.000746) × (86.2693) = 0.0644 real long-run per capita daily sales increase, and (0.0644) × (30) = 1.93 ounces total long-run per capita sales increase.

Table 1. Estimated Coefficients for Constrained Second-Degree Polynomial Lag Model by SMSA

Independent Variable	New York City Coefficient	New York City t-ratio	Albany Coefficient	Albany t-ratio	Syracuse Coefficient	Syracuse t-ratio
Jan.	0.07818	0.96	−0.0206	−0.07	0.2103	1.04
Feb.	0.2964	3.85	0.3118	1.11	0.4390	2.20
Mar.	0.2524	3.24	0.4157	1.51	0.3478	1.76
Apr.	0.1052	1.21	0.3128	1.00	−0.1334	−0.60
May	−0.0322	−0.38	0.0047	0.01	−0.2939	−1.42
June	−0.1753	−2.08	−0.7738	−2.72	−1.0356	−5.01
July	−0.8813	−11.67	−1.6777	−5.99	−1.8136	−8.96
Aug.	−0.7682	−10.08	−1.1993	−4.26	−1.5596	−7.76
Sept.	−0.1822	−2.42	−0.0201	−0.07	0.0249	0.12
Oct.	0.0079	0.10	0.3574	1.28	0.4840	2.43
Nov.	−0.1003	−1.34	0.3300	1.20	0.2292	1.16
A_t	13.7712	1.80	15.8578	0.86	5.7308	0.45
A_{t-1}	16.9146	3.52	11.5888	1.35	3.5886	0.67
A_{t-2}	17.8825	4.16	7.8685	0.92	1.9195	0.27
A_{t-3}	16.6751	3.66	4.6970	0.48	0.7232	0.12
A_{t-4}	13.2921	3.17	2.0741	0.29	0	0
A_{t-5}	7.7338	2.85	0	0	0	0
A_{t-6}	0	0	0	0	0	0
Sum A_{t-i} coef.	86.2693	4.16	42.0862	1.34	11.9622	0.67
Income	0.000575	0.79	0.0090	7.31	0.000699	1.04
Price	−2.9645	−5.66	−2.7150	−0.86	−1.9136	−1.16
Constant	7.50	2.41	−19.7906	−4.09	12.45	5.84
R^2	0.95		0.86		0.91	
DW	1.33		1.32		1.92	

Profitability of the Expanded Advertising Program

To estimate net producer returns from the intensified advertising program, the value of the increased milk sales attributed to advertising is compared with the increased cost of financing the Dairy Promotion Order. Utilizing the estimated models and their respective long-run advertising coefficients, the expected sales during a given period of the expanded advertising program are compared with the expected sales in the same period assuming advertising expenditures remained at the pre-Order level. Specifically, the expected sales during post-Order 1973, the first full calendar year of the expanded advertising program, are compared to expected sales at the pre-Order 1971 expenditure level, the calendar year immediately prior to the implementation of the Promotion Order. Actual post-Order prices and incomes were used to estimate pre-Order sales. Hence, the difference between the expected pre-Order and expected post-Order sales can be attributed to the impact of the expanded advertising program.

Because of the relatively short time period covered in this analysis, the advertising program was assumed to have no effect on the total quantity of milk produced.[6] Rather, the effect of the advertising program increased the utilization of total milk in the fluid Class I market. Reallocating milk from Class II to Class I increases the farm value of milk by approximately $2.40 per hundredweight (USDA, sec. 1002.5). Thus, the farm value of each 1 ounce increase in fluid milk sales is $0.0016.

The net return to producers from the increased advertising expenditures is shown in table 2. In the New York City market, the increase in the farm value of milk sold exceeded the increased cost of the advertising program by 10.5¢ per capita. The net returns for Albany and Syracuse are estimated to be 2.8¢ and −3.8¢ per capita respectively.

The reasons for the variation in producer returns among the markets are not fully understood; however, the average per capita consumption levels prior to the expanded advertising effort were, and still are, substantially lower in New York City than in either Albany or Syracuse. In particular, an inverse relationship was observed between net producer returns to advertising and average per capita consumption levels, that is, while the respective returns were estimated to be 10.5¢, 2.8¢, and −3.8¢ per capita in New York City, Albany, and Syracuse, average daily per capita consumption levels during the period of analysis were 8.69, 12.01, and 13.75 ounces for the three markets respectively. Further, the differences in the estimated return to fluid milk advertising among the three markets are not inconsistent with other economic and demographic market differences.[7]

[6] A positive supply response resulting from a successful advertising program would tend to dilute the net returns to advertising.

[7] Utilizing alternative evaluation techniques, previous empirical

Table 2. Estimated 1973 Producer Returns from Increased Advertising by SMSA

	NYC-SMSA	Albany-SMSA	Syracuse-SMSA
Estimated per capita sales of fluid milk:			
with advertising at 1973 level[a]	3211 oz.	4608 oz.	5032 oz.
with advertising at 1971 level	3117	4562	5019
Per capita sales gain attributed to increased advertising	94 oz.	46 oz.	13 oz.
Farm value of per capita sales increase[b]	15.0¢	7.4¢	2.1¢
Per capita advertising expenditure, 1973	6.9	6.8	7.7
Per capita advertising expenditure, 1971	2.4	2.2	2.5
Cost of increase in advertising	4.5¢	4.6¢	5.2¢
Producer's net return per capita from increased advertising	10.5¢	2.8¢[c]	−3.1¢

[a] Sales were estimated using 1973 and 1971 average monthly advertising expenditures, actual 1973 prices, actual 1973 income and the estimated coefficients reported in table 1.
[b] Assuming no supply response and a Class I, Class II price differential of $2.40/cwt., each additional ounce of fluid milk sales has a farm value of $0.0016.
[c] Even though the farm value of sales gain in Albany is positive, one cannot maintain a high degree of confidence in this estimate given the precision of the estimated long-run advertising coefficient in Albany, i.e., t-ratio equals 1.34.

Conclusions

Notwithstanding a positive influence of advertising on sales in all markets, marked intermarket differences in the net producer returns from increased advertising were observed. Although the exact reasons for these differences are not known, substantial differences in consumption levels exist among the markets. Most important to the market researcher, however, is that conspicuous intermarket differences accentuate the need for prudent market-by-market analyses of advertising programs.

The experience of New York State dairy producers' increased investment in milk advertising can provide an important economic input for use by other agricultural commodity groups contemplating expanding their own advertising programs. The techniques and procedures used in this analysis provide a framework within which the producers' return to increased levels of advertising can be evaluated.

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research also reveals substantial differences among the three markets with respect to consumers' attitudes toward fluid milk as a beverage (Eiler and Thompson), and the relation between the probability of milk use and awareness of milk advertising themes (Thompson and Eiler). In these studies, the attitudinal and milk use differences were influenced by various economic and demographic consumer characteristics.

Development of a Systems Approach for Livestock Research in ERS

Richard J. Crom

Systems analysis is today's way of research be it in the social or physical sciences, but it has taken many directions, each of multiple dimensions, so when a researcher writes about his work in systems analysis, the reader often must ask his definition of it. This paper traces the development of the systems approach to research in the Meat Animals Program Area of the Economic Research Service and defines the current concept of systems research in this program area.

A Bit of History

Consider the evolution of economic research concerning the livestock industry in ERS since 1961. Production economics research, marketing economics research, and outlook and demand analyses were conducted in three separate divisions. During the 1960s, there was growing concern that the farmgate was no longer a meaningful criterion for the division of economic research. Also, outlook personnel needed the support of research in more formalized forecasting procedures.

As a consequence, the administrator of ERS commissioned Shaffer to investigate possible frameworks for doing economic research in agricultural marketing. He summarized his findings in a paper which became the basis for discussion at a conference in Lincoln, Nebraska in 1968. The concept of subsector analysis was introduced to the profession by this pioneering paper.

A quarterly price-output model of the beef and pork sectors developed in the Marketing Economics Division to simulate the expected results of structural change was completed in 1969; it seemed to fit many of Shaffer's notions of a formal, ordered, dynamic analysis of the effects of change on a total commodity production-processing-distribution sequence (Crom 1970). An internal, unpublished paper prepared by Crom discussed the future use of the systems approach and subsector models of economic analysis of the livestock industry. Formulation of the hog-pork subsector model was just commencing at that time so the chief function of this paper was to guide management's thinking to define the ERS role in this pioneering effort between the state experiment stations and ERS in commodity subsector analysis (Honegger).

At that time, a "beef team" was organized among researchers in the Farm Production Economics Division to conduct a comprehensive analysis of the beef industry. The "beef team" commenced with a thorough description of the cow-calf and cattle feeding subsystems including probable future supply response. (The two publications from this effort are among the most popular ERS has issued: Gustafson and Van Arsdall; Van Arsdall and Skold.)

Use of the quarterly model to simulate long-run effects of several situations developing in the livestock industry had convinced managers of livestock research in ERS that systems analysis was the way to pursue our livestock research program, that both production and marketing research needed to be integrated, and that the systems approach was more than a model—it was a framework for research organization.

A workshop held in 1970 to initiate the systems approach in the Animal Products Branch of the Marketing Economics Division focused administrative attention on the efforts that were currently under way in both the Farm Production and Marketing Economics Divisions (Manchester). Subsequently a team of ten junior and senior level economists was commissioned to prepare a paper outlining a research and information program for the beef subsector (Crom et al).

A Suggestion for Systems Research

The team report was submitted to the directors of the Food and Fiber Divisions of ERS on January 1, 1973. While addressed to the beef subsector, its concepts can easily be adapted to any commodity. The basic research plan consists of four steps; the first two are simultaneous.

The initial endeavor involves construction of an enterprise budget for each significant type of firm involved in each production and transfer process. This includes marketing agencies. If types of enterprises are not readily identifiable, initial efforts would be directed towards qualitative identification of the types of firms that have major differences in

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Much of the material presented in the article relies heavily upon recommendations of a research-planning team report headed by the author and the research project statements subsequently developed in the Meat Animals Program Area. The support and encouragement of W. T. Manley, J. E. Lee, and K. R. Farrell, division directors and deputy administrator, ERS, deserve special recognition.

structural organization and are believed to be involved with a significant portion of firm volume. Then, input-output coefficients for each type of firm would be used to form firm budgets. A linear programming format could be used to assess the impact of a change in economic or technical factors on the optimum organization of the firm. Functional relationships could be estimated to determine probable changes in prices and output due to changes in either internal structure or external economic change. While this step in the research plan deals almost entirely with data development, it is necessary because much of the existing data are output data—either quantities from the production process or prices resulting from the transfer process—rather than input-output relationships.

Structural identification of the industry is the simultaneous initial endeavor. Information would be maintained as to the number of firms of each of the types identified for budgeting and the volume handled by each. This information would be used to estimate aggregate effects of differential adjustments by significant types of enterprises. Current structural identification is minimal. The capacity distribution of cattle feedlots is about all that is currently reported. Analysts need to know the number of firms, location, capacity, tenure, and capital source(s) for each type of major technology budgeted. Development of an adequate information base would require extensive effort in cooperation with the Statistical Reporting Service and the Bureau of the Census.

Identification of and understanding economic and noneconomic forces which bring about changes in the structure identified is the subsequent research activity recommended in the team report. Research in this area would focus on why and how management reacts to economic and noneconomic forces. To the extent possible, empirical functional relationships would be estimated for use in forecasting structural change.

These research and data development efforts culminate in the development of an overall systems model. This model should be capable of incorporating the appropriate submodels of the production and transfer processes and the structural shifts necessary to analyze coefficients and exogenous economic variables. It would encompass the beef industry from farm or ranch production of feeders to consumer purchases of beef. Such a model must be developed in stages, so that it becomes progressively more useful in supplying information relative to decisions as more detail is built into the model. But it must be constructed so that it becomes useful very early in its development and then is refined in successive stages. This effectively summarizes the ultimate goal of the three prior elements of the core program—building and updating a bank of coefficients or data comparable for all regions in the United States.

An Associated Information Program

The team report also considered an information program as a vital part of the systems package. The team recommended that the ERS research information program for livestock be expanded to service the clientele, especially those in the private sector where contact is currently made through research reports and the news media. While information needs of public policy makers can be serviced through memos and special reports, a regular and timely means of disseminating results of policy analysis is needed so that the clientele in the private sector can react to such research results in time to have an input into policy decisions.

Relocation of the control of all information activities to a unit within ERS would result in more timely dissemination of research and outlook information and in use of more appropriate media. A director of information within ERS could develop lists of clientele interested (or assumed to have an interest) in the results of beef research. Research reports would be distributed to people on these lists as soon as possible. Special reports might be distributed to these groups, either in lieu of formal publication or before the formal publication is prepared. Information specialists might be assigned to draw on results of different pieces of research to relate their findings to one particular issue.

While the current program provides timely analysis of the beef and pork situation, forecasting methods should be improved. As more reliable price forecasting models are developed, their results would serve as input to the current work.

Three types of information which would be a by-product of the basic research effort would be generated on a continuing basis. The structural description of each of the production and transfer processes budgeted would be published annually. Costs and returns series would be published for each production and transfer enterprise for the major types of organizations. In the case of cattle production and feeding, a regional orientation would be desirable. A long-term outlook for the forthcoming ten years would be issued every three years. This length of projection is needed for a meaningful planning horizon. Regular short-term outlook would point out changes in the situation in the intermediate period.

Implementing the Plan

The team report was most timely since the reorganization of the commercial agricultural divisions of ERS was just commencing in early 1973 to better service a systems framework.

Under the reorganization, the research and information program of the Meat Animals Program Area is organized under five projects.[9] One of these

covers a piece of ongoing basic research, and another covers demand analyses aimed at support of the outlook work. Two projects, "Structural Characteristics of the Beef-Pork Subsector" and "Aggregate Analyses of Industry Performance," are patterned after the core research effort suggested in the team report.

For the recommendation, Structural Identification of the Industry, the corresponding project objective calls for identification of significant types of livestock production, slaughter and processing, and retail and institutional distribution enterprises by region. Description of the structure of the industry will be made in terms of the number of firms involved in the enterprises identified and their share of industry output.

For the team recommendation, Construction of Enterprise Budgets for Each Significant Type of Firm, the corresponding project objective (or research approach) indicates that data describing economics of the enterprise will be developed. Initially, types of production, processing, and distribution enterprises believed to have major differences in structural organization and involve a significant portion of firm volume will be identified. Budgets including gross and net returns will then be developed for each of these significant types of enterprises in the industry.

For the team recommendations, Identification and Understanding Economic and Noneconomic Forces Affecting Structure and Development of an Overall Systems Model, the corresponding project objectives (or research approach) states: Develop overall systems models of livestock meat industry capable of incorporating the appropriate submodels of production and transfer processes and the structural shifts necessary to analyze the overall effects of a change in policy, technical or structural coefficients, or exogenous economic variables.

Commencing with the 1976 fiscal year, the work of generating budgets, enterprise identification, and identification of variables affecting behavior by type of enterprise should be well along. Many demand parameters should also be updated and refined. Also, most of the analyses of the beef and pork subsectors using existing models and their underlying concepts can be integrated into overall systems models of the livestock sector. New structural data will allow developments of models aimed at more comprehensive dynamic analysis. Such models must be developed in stages so that they become progressively more useful in supplying information relative to decisions as more detail is built into them. Such systems models summarize the ultimate goal of the other elements of our core program—building and updating a bank of coefficients and data comparable for all regions of the United States.

The fifth project in the program area, Outlook and Situation—Long-Run Projections, extends this long-term ongoing activity in light of the information program presented in the team report. In addition to conventional outlook analyses, the research approach section further states that "when developed and operational, outlook personnel will consider results of formal quantitative models of the livestock sector." Outlook analysts will have benefit of consultation with economists in the Meat Animals Program Area who are specializing in economic analysis of livestock production and marketing in major geographic regions. Accordingly, five economists have been designated as regional analysts for the South, North Central, Southwest, Northern Plains, and Western regions to interact with outlook personnel.

Long-run objectives developed under exogenous assumptions will initially be used on existing supply and demand models. Eventually, these projections will be based on more comprehensive models of the industry constructed under associated research projects.

Progress

During the first two years of operation, progress has been on track. The five regional analysts concerned with the production subsystems have completed a tentative identification of the enterprise structure of the beef cow-calf, cattle feeding, hog and sheep production subsectors. Budgets for the types of enterprises (totaling several hundred) are being constructed and will be maintained on the budget generator system. A paper on the structure of the cow-calf subsector was presented at a National Extension Workshop (Crom 1974). Structural identification of the slaughter-processing sector is nearing completion. A contract was let to a firm of consulting engineers who specialize in packer-processor plant design to construct budgets for these enterprises. This work provides much of the new data needed for subsector analysis, especially supply response in addition to providing timely information to the industry and public concerning enterprise costs.

Obviously, formal quantitative analyses of behavioral relationships and model construction cannot commence until basic data are developed, but the model team has met to give initial consideration to their assignment.

As part of the information program, typical budgets were included in the *Livestock and Meat Situation*. Specific forecasts were introduced indicating predicted slaughter and prices by quarter. Most budgets should be "on line" in the budget generator by the end of the fiscal year. Preliminary estimates of enterprise structure should be refined through the Annual Economic Survey of Agriculture which is included in the Department's budget request for the 1976 fiscal year.

Availability of these data will allow the regional analysts to turn their attention to analysis of the forces of structural changes including estimation of behavioral relationships and supply response parameters. Finally, the modeling team will focus on development of a prototype subsector model which can be expanded and refined as several analyses advance.

Results of individual demand analyses and existing models will bear on price and supply forecasts. ERS hopes to publish a ten-year projection by the end of the fiscal year based on extension of the price-output model developed in cooperation with Iowa State University. If the survey firming up the structural identification of the industry is completed, a descriptive report should be most timely, and a handbook of enterprise budgets developed from the budget generator should be a very useful report.

Economists at state experiment stations have usually been free to conduct investigations concerning all or any segments of the industry unhampered by organizational constraint. ERS economists have now achieved this flexibility, but necessary attention to local problems by state personnel have often limited industry-wide analysis. When complete, the ERS industry-wide systems approach may provide a frame of reference as background for local problems. On the other hand, state experiment stations' exhaustive analyses of local issues may result in significant modification of the national systems model. Finally, state experiment system researchers may both use and update enterprise budgets (budget generator).

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An Econometric Analysis of the Sorghum Market

Sujit K. Roy and M. Edwin Ireland

Sorghum has become an important feed grain in the United States during the past decade. Production of sorghum has increased substantially in recent years and reached 875 million bushels with an estimated value of $1 billion for the 1971–72 crop year. Rising demand for beef and the production potential of the crop in semiarid areas gave a major impetus to the upward trend in sorghum production. The expanding domestic demand for sorghum is also supplemented by a world market in which the United States is the major exporter. The basic objective of the study was to identify and estimate the major structural relationships which influence annual sorghum prices in the U.S. domestic market. Demand elasticities are estimated from the model to further analyze the domestic market. The paper also includes a comparison of alternative statistical estimates of the model with special reference to *ex post* estimation of endogenous variables in the system.

Supply and Utilization of Sorghum

Annual sorghum supply consists of total production during the crop year beginning October 1, and the storage stocks carried over from the preceding crop year. Imports of sorghum, averaging approximately 50,000 bushels per year, are negligible relative to total U.S. supply. Sorghum production increased during the mid-1960s and early 1970s, while storage stocks—mostly under loan or owned by the Commodity Credit Corporation (CCC)—were as much as one-half or more of the annual supply. However, end-of-year stocks declined sharply in recent years, specifically since 1965.

Domestic consumption of sorghum as feed has increased substantially over the past decade, rising from less than 500 million bushels prior to 1965 to nearly 700 million bushels in the early 1970s. The trend was due mainly to the increased feeding of beef cattle and an expanding recognition of sorghum as an acceptable substitute for corn as a feed grain. The increased use of sorghum also coincided with the shift of the feedlot industry from the Midwest where corn predominates to the Southwest where sorghum is a major feed crop. Annual exports during 1963–71 ranged from 106 to 166 million bushels except for 1965 and 1966 when the average volume was 257 million bushels.

Significant changes seemed to have occurred in the price-determining process within the sorghum sector over the past two decades. Production of sorghum through 1962 generally exceeded total use; prices were determined mainly by the CCC loan rate, and surpluses that could not be sold at this price were accumulated under loan or through deliveries to CCC. From 1963, total use of sorghum surpassed production; the average price for the year was higher than the loan rate, and CCC stocks declined sharply. In view of these changes, free market forces were sufficiently dominant since 1963 so that a model based mainly on such forces could be developed to study the structural relationships of the most recent period.

The Econometric Model

Earlier studies concentrated primarily on the analysis of the overall feed grain market with special emphasis on corn (Foote; Foote et al.). In Meinken's study, corn price and the sorghum-corn supply ratio were the major determinants of sorghum price. Under an alternative formulation, variations in sorghum production relative to corn supply explained most of the deviations of sorghum price from the price of corn (Meinken, pp. 60–65). Quantities in other disposition categories such as storage stocks and exports were negligible for most years under the study. In recent years, however, market supply and volumes in these disposition categories have reached levels high enough to warrant an analysis of the structural relations by major usages. Accordingly, the present model includes an equation for each of the major utilization subsectors:

$$QF_t = f(PS_t, PC_t, AU_t), \tag{1}$$
$$QX_t = f[(PS_t/PC_t), PX_t, QX_{t-1}], \tag{2}$$
$$QS_t = f(PS_t, QS_{t-1}), \tag{3}$$
$$PX_t = f[PS_t, (QW_t/QW_{t-1})], \tag{4}$$

and

$$QF_t + QX_t + QS_t = QN_t + QS_{t-1}. \tag{5}$$

The subscripts t and $t-1$ represent the current and the preceding years, respectively, and QF = quantity of sorghum used for feed in the current crop year (million bushels); PS = average price of No. 2 yellow sorghum at Kansas City during the current crop year (dollars per hundred pounds); PC = average price of No. 3 yellow corn at Chicago during

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Texas Tech University, College of Agricultural Sciences, Manuscript T-1-127. The model and related statistical results in this paper are condensed from Texas Tech University, College of Agricultural Sciences Publication T-1-122 (Roy and Ireland).

the current crop year (dollars per bushel); AU = grain-consuming animal units (million units); QX = quantity of sorghum exported during the current crop year (million bushels); PX = average price of No. 2 yellow sorghum at Gulf ports during the current crop year (dollars per hundred pounds); QS = quantity of sorghum in storage at the end of the crop year (million bushels); QW = world corn and sorghum production in current crop year net of U.S. production (million metric tons); and QN = total domestic production of No. 2 yellow sorghum during the current crop year net of the quantity used for food, seed, and industrial purposes (million bushels). (Data for these variables were obtained from USDA, *Feed Situation* and *Feed Statistics*, with the exception of world feed grain production series which was compiled from UN, FAO.)

The current endogenous variables in the system are QF_t, QX_t, QS_t, PS_t, and PX_t, and the remaining variables are either lagged values of the endogenous variables or determined outside the system.

In equation (1), the relationship between the domestic consumption of sorghum as feed and corn price is expected to be positive. The higher the price of corn relative to the price of sorghum, the more sorghum will be substituted for corn as a feed. The number of animal units (AU_t) is a demand shifter and is expected to have a direct effect on QF_t.

The ratio of sorghum price to corn price was used in equation (2) to represent the influence that the domestic demand for sorghum relative to corn exerts on the quantity of sorghum exports. The quantity of U.S. exports of sorghum during the previous year (QX_{t-1}) was included to represent the influence of factors which are not purely economic in nature, such as the desire to maintain established foreign trade relations among trading partners. Foreign trade patterns and levels tend to be maintained over the years once they are established.

With reference to equation (3), if the current domestic price is relatively low and the export market is weak, storage stocks will tend to increase. The relationship between the domestic sorghum price and the end-of-year storage stocks was therefore postulated to be negative. Storage stocks at the end of the previous crop year (QS_{t-1}) would be expected to affect QS_t directly, since a large carryover from the preceding period may create a relatively large surplus supply of sorghum during the current year, *ceteris paribus*.

The relation between domestic price of sorghum (PS_t) and export price (PX_t) is expected to be positive, while the world production of major feed grain (QW_t) is expected to exert an inverse effect on the export price. The ratio QW_t/QW_{t-1} was introduced instead of QW_t to reduce the observed high direct correlation between the export price and the world production variable. When QW_t/QW_{t-1} is low, the demand for export movement may become large, and prices at the Gulf may tend to be high relative to prices in producing areas. Equation (5) is the closing identity of the system and equates the total utilization of grain sorghum with the total available supply for the crop year.

Estimates and Evaluation of the Model

All four stochastic relations in the model are overidentified and are estimated by using both two-stage and three-stage least-squares (2SLS and 3SLS) procedures. Given the limited number of observations, the first-stage ordinary least-squares (OLS) equations were based on a subset of the exogenous variables. The estimates of the stochastic equations, based on annual data for the period 1963–71, are presented in table 1.

The estimated coefficients for PS_t and PC_t in equation (1) are of special significance. It has often been presumed that consumption and prices of sorghum have been essentially determined by the price of corn or the supply-demand situation in the corn sector. However, the price of sorghum, PS_t, appears to have a substantial inverse effect on the domestic consumption of sorghum as feed. A relatively large positive coefficient for corn price indicates a significant substitution between corn and sorghum.

The sorghum-corn price ratio, PS_t/PC_t, and the lagged volume of exports, QX_{t-1}, appear to be the more important variables in the export relation, equation (2). Although the coefficient for export price, PX_t, is small relative to its standard error, the variable was retained in the relation because of the appropriate positive sign of the coefficient.

In equation (3) of table 1, the coefficients for both variables, PS_t and QS_{t-1}, are large relative to the standard errors and are consistent in sign with the expected causal relations. The domestic price of sorghum appears to influence the level of storage stocks to a considerable extent. Under an initial phase of model specification, the loan rate was included as an independent variable in the storage equation. The net effect of a loan rate which was high relative to the prevailing market price of sorghum was presumed to be an increased volume of storage stocks. However, the estimated coefficient for the variable was inconsistent in sign. As discussed earlier, the market price remained above the loan rate during the period of study and may have reduced the incentive to withhold sorghum from the market for any considerable length of time. However, in shorter-run analysis, the loan rate may become an important factor.

The results of equation (4) indicate that the domestic price of sorghum (PS_t) is the most significant determinant of PX_t. The production variable (QW_t/QW_{t-1}) shows the expected inverse effect on the export price. Apparently, the export

Table 1. Estimated Coefficients of Structural Equations of the Sorghum Model

Equation	Estimation Method	Constant	PS_t	PX_t	PS_t/PC_t	PC_t	AU_t	QX_{t-1}	QS_{t-1}	QW_t/QW_{t-1}
(1) QF_t	2SLS	−2296	−619.9	—	—	771.5	28.65	—	—	—
			(201.4)[a]			(230.2)	(3.884)			
	3SLS	−2458	−530.6	—	—	556.6	30.85	—	—	—
			(132.3)			(182.5)	(2.373)			
(2) QX_t	2SLS	953	—	16.02	−539.6	—	—	0.4126	—	—
				(63.43)	(129.8)			(0.1665)		
	3SLS	628.7	—	8.109	342.9	—	—	0.5132	—	—
				(49.59)	(115.3)			(0.0816)		
(3) QS_t	2SLS	898.3	−407.6	—	—	—	—	—	0.7181	—
			(159.1)						(0.1097)	
	3SLS	816.5	−379.9	—	—	—	—	—	0.7827	—
			(149.7)						(0.1024)	
(4) PX_t	2SLS	−0.1485	1.28	—	—	—	—	—	—	−0.1693
			(0.317)							(0.1081)
	3SLS	−0.3064	1.389	—	—	—	—	—	—	−0.2181
			(0.3093)							(0.1037)

[a] Standard errors of coefficients are presented in parentheses.

price equation in the present form is a simplified specification and a more complete formulation remains beyond the scope of the present study.

Differences in the magnitude of the model's 2SLS and 3SLS coefficients in some cases were substantial, particularly for the price variables. As expected, the 3SLS coefficients appear to be statistically better established than the 2SLS estimates.

Estimates of the five endogenous variables, obtained from the reduced form equations, were compared with actual values for the study period. The 3SLS estimates produced two turning point errors—one each for QF_t and QX_t (see table 2). This is particularly noteworthy since most variables fluctuated over a fairly wide range during the period. Estimation errors were further examined by Theil's inequality coefficient, U_2 (table 2).[1] The coefficients, which are all less than unity, indicate that on the average both models produced better estimates than would result from a naive "no-change" extrapolative model. The U_2 coefficients for all variables, with the exception of QS_t, for 3SLS are smaller than those for 2SLS. Estimates of the endogenous variables using 3SLS therefore appear to be generally more accurate than the corresponding estimates obtained from 2SLS in the present study. The relatively small U_2 coefficients for PS_t and QF_t based on 3SLS are of special importance, since it is indicative of the accuracy of estimates for two crucial variables in the model. The average magnitude of errors for PS_t was 1.5% of the mean price for the period, and the corresponding error for QF_t was 4.3%.

[1] The inequality coefficient U_2 is defined as

$$U_2 = \sqrt{\Sigma(P_t - A_t)^2 + \Sigma A_t^2},$$

where A_t is the actual change in the variable, and P_t represents the corresponding estimated change (Theil, pp. 27–28).

Demand Elasticities in the Domestic Market

The direct price elasticity of demand, based on the 3SLS structural equation and estimated at the mean price and quantity, was −1.90. While price elasticity for corn is low (Brandow, p. 80; Foote et al., p. 39), the demand for sorghum would be relatively elastic since sorghum comprises a small portion of the feed grain sector. The cross-price elasticity was 1.20 at the means of corn price and quantity of sorghum sold in the domestic market.

Both direct and cross-price elasticities of demand for sorghum declined in absolute value during the period of study, partly reflecting the effect of increasing supply of sorghum in the domestic market (QF_t). The direct price elasticity computed from the 3SLS estimates changed from −2.53 in 1964 to −1.51 in 1971, while the cross-price elasticity decreased from 1.64 in 1964 to 0.91 in 1971.[2] Conceiv-

[2] The direct price elasticity for each year was computed by using the 3SLS estimates of domestic sorghum price, $\hat{PS}_t$, and quantity, $\hat{QF}_t$. The cross-price elasticity was based on the 3SLS estimate of quantity of sorghum, $\hat{QF}_t$, and the actual annual corn price, PC_t.

Table 2. Turning Point Errors and Inequality Coefficients for the Endogenous Variables, 1963–64 to 1971–72

Endogenous Variables	Turning Point Errors 2SLS	Turning Point Errors 3SLS	Inequality Coefficients, U_2 2SLS	Inequality Coefficients, U_2 3SLS
PS_t	1	0	0.29	0.25
PX_t	1	1	0.86	0.85
QF_t	1	1	0.80	0.41
QS_t	0	0	0.44	0.50
QX_t	2	0	0.75	0.44

ably, with expanded use of sorghum, the direct price elasticity of demand for sorghum would tend to approach unity or less. For example, based on the 3SLS equation (1) and actual values of the exogenous demand shifters—AU_t and PC_t—for the 1971–72 crop year, it was estimated that the elasticity would have been unity if the domestic consumption and price were about 906 million bushels and $1.71, respectively.[3] It appears that an increase of sorghum supply in the domestic market would have caused a less than proportionate fall in sorghum price. Thus, the domestic sale of sorghum could have been increased to a certain extent to increase the total return from the domestic market.

Concluding Remarks

The study was an effort to develop and analyze the structural relations in the sorghum market which in recent years has become a significant part of the feed grain sector. The postulates regarding the major causal relations in the sorghum sector were generally corroborated by the results of the model. In recent years, the free market forces of supply and demand in the sorghum sector have played a relatively strong role in the price-determining process which in earlier years was largely dependent on the price support program and CCC policy. Furthermore, the structural relations in the grain sorghum market did not appear to be entirely dominated by corn price or by the supply-demand situation in the corn sector as such. Given the recent market situations and a relatively price-elastic demand, the potential of higher total return from increased supply of sorghum in the domestic market appeared to be reasonable. Methodologically, estimates of endogenous variables obtained from the 3SLS equations generally involved smaller errors than the corresponding estimation errors for the 2SLS equations. Estimated values of domestic sorghum price, especially those based on the 3SLS equations, exhibited a high degree of accuracy.

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[3] It is assumed that some increase in sorghum supply would not significantly affect corn price since sorghum's share of the domestic feed grain market is relatively small.

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Increasing Response Rates in Mailed Questionnaires: Comment

Ralph M. Brooks, Vernon D. Ryan, Brian F. Blake, and John R. Gordon

In an article recently published in this *Journal*, Buse stressed the utility of mail questionnaire surveys and elaborated on the importance of personalization in generating an unusually high response rate from them. The use of mailed questionnaires seems further justified given the decrease in governmental and foundation funding. This, combined with the continual rise in costs associated with traditional survey research techniques, makes mail questionnaires more important and in need of further evaluation.

As expressed by Buse, personalization in a mail questionnaire often involves persistence (repeated contact with subjects) and the two are frequently intertwined. On the surface, a personalized approach appears to be the answer in stimulating high response rates. Yet we question whether personalism is necessary and suggest that a closer look at the role persistence and personalism play in yielding high response rates may be in order. The purpose of this note is to review the Buse procedure as an example of the importance of persistence to the personal approach, then compare the results to another study which was impersonal, but persistent in its data collection. From this comparison, it may be possible to evaluate the importance of personalization in mail questionnaires.

Alternate Approaches

Buse achieved his high response rate by utilizing an intensive personalized approach at each stage of his mailing. He first sent two letters of introduction to 880 previously identified agricultural corporation presidents. One of these letters explained the purpose of the project and asked each president to delegate responsibility for completing the questionnaire (which would be mailed in two weeks) to the appropriate person in the corporation. A return post card was included for identifying the responsible person's name and address. The second letter, signed by the dean of the College of Agriculture, supported the researchers and legitimized the project. In subsequent follow-ups, he used personal letters, special delivery mailings, postage stamps on the letters (rather than metered postage), and, finally, a telephone call to the nonrespondents. This process generated a response rate above 90% with costs running $3.45 per usable response.

As expressed by Buse, his entire methodology relied heavily on the personal approach in an attempt to "anticipate resistance and increase respondents' personal involvement" (p. 504). Some form of personalism at each stage of mailing was used to meet these objectives. The letter from the dean made the project seem important to the potential respondent but was probably used more for convincing the corporation president to cooperate. The importance of the study was further stressed by having the corporation president appeal to an employee to complete the forthcoming questionnaire. Finally, Buse studied only agricultural corporations, a homogeneous group.

The Buse situation could almost be described as a researcher's utopia—personal contact, the top leader in an organization designating another person to complete the questionnaire, a homogeneous group, and much prior data already available on their activities. Yet not every situation in which socioeconomic data are to be gathered has a corporation president to stimulate response. Frequently, in fact, the population itself is not finite. Suppose the population in question was heterogeneous, precluding many of Buse's personalization steps. Can a less personalized approach also generate favorable results? Answering this question may also help us understand the role of persistence in mailed questionnaires.

In the spring of 1973, a probability sample of Indiana households received a mail questionnaire.[1] The focus of the study, stemming from the researchers' interest in rural development, was to obtain data concerning Indiana residents' preferences for the type of community they most like and their satisfaction or dissatisfaction with a range of community services. Table 1 presents the procedures followed in the Indiana study in comparison with Buse's methodology.

Each mailing in the Indiana study, with the exception of the certified letter, de-emphasized personalization. The letters were mass produced with a "Dear Community Resident" greeting. Instead of typing each individual envelope, pressure sensitive address labels were obtained from the listing of

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[1] Locating a list of households statewide is indeed a difficult task. The sample was obtained from a list of automobile registrations through the R. L. Polk Co. A more detailed explanation of the methodology can be found in Brooks et al.

Table 1. Comparison of Wisconsin and Indiana Mail Questionnaire Procedures

Contacts with Respondents	Wisconsin	Indiana
Stage 1	Two letters and a self-addressed return postcard (on which to list the name of the designated respondent) sent to corporation president	
Stage 2	Letter, questionnaire, and return envelope sent by special delivery mail	Cover letter asking an adult member to respond, a questionnaire, and a return envelope sent to each household
Stage 3	Follow-up letter sent encouraging respondent to complete questionnaire and thanking him	Reminder postcard sent one week after initial mailing
Stage 4	Replacement questionnaire, cover letter, and return envelope sent by special delivery mail	Follow-up letter, replacement questionnaire, and return envelope sent two weeks after stage 2
Stage 5	Telephone call made to non-respondents	Replacement questionnaire, cover letter, return envelope, certified mailing sent two weeks after stage 3
Total time	9 weeks	6 weeks

auto registrations. Letters were not individually signed. Although the questionnaires were numbered, the respondent was assured anonymity would be maintained.

Results of Two Procedures

Buse reports a response rate of 91% with personalized procedures, whereas our procedures, emphasizing a depersonalized approach, generated a 71% response. Obviously, the Wisconsin rate is higher. However, part of this difference may be a function of how the rates were calculated. Apparently, the 91% came from considering every corporation as a respondent unless they provided "no response." Hence, a corporation writing back stating they were dissolved, out of business, or classified as a nonagricultural corporation was counted as a respondent.

Although both response rates were substantially higher than most reports of response rates in surveys involving mailed questionnaires, we still lack a mechanism of comparing the results to the two approaches.

Perhaps looking at the type of response for both Wisconsin and Indiana may provide a better assessment of the two procedures. In table 2, data for the 880 Wisconsin corporation presidents and the 8,037 Indiana households are presented. When comparing the respondents (as a percentage of the initial sample in both studies), it seems reasonable to us that respondents classified as nonagricultural corporations, dissolved, or out of business (Wisconsin study) are actually unusable responses. This also applies to those people who moved out of the state, are deceased, or were unable to be located (Indiana). In this manner, the 63.4% from Wisconsin and the 66.9% from Indiana appear comparable. In the "no response" category, a large difference exists between both studies. The larger no response rate in the Indiana study (27.2%) may be the price one pays when surveying heterogeneous populations, that is, the risk for a larger "no response" category may be greater than situations where the population is homogeneous. However, the 66.9% response rate from the Indiana study is very encouraging considering the diversity of the population and traditional low levels of response rates experienced in past mail surveys.[2]

Regardless of how the response rates are calculated, both methods are sufficiently high to warrant further investigation of the basic methodology.

[2] Conventional ways of calculating response rates would mean eliminating those responding but not meeting the criteria of a respondent. This would result in an even higher response rate, i.e., 71% for Indiana.

Table 2. Comparison of Response Rates from Two Separate Studies Involving Mail Questionnaires

Type of Response	Wisconsin #	Wisconsin %	Indiana #	Indiana %
Responded	558	63.4	5,365	66.9
Unused responses	239	27.1[a]	479	5.9[b]
No response	83	9.5	2,193	27.2
Total	880	100.0	8,037	100.0

[a] Classified as nonagricultural corporation, dissolved, or out of business.

[b] Classified as moved out of state, deceased, or unable to locate.

Furthermore, when comparing costs associated with the two surveys, Buse's study was $3.45 per usable questionnaire as compared to Indiana's $1.64. This difference numerically may not warrant discussion, yet the difference can be a significant savings in large samples.

Although the questions of personalization and persistence need to be further studied in an experimental design, tentative indications from the Indiana study would suggest that personalization may not be that necessary in eliciting high response rates from the general public. Both studies, however, emphasize the importance of persistence through several follow-ups.

Finally, it would seem that the advantages of the "personal" approach over those of the "impersonal" but persistent method may be debatable. Researchers, however, probably should not necessarily assume that past investigations unequivocally demand they use the more expensive and elaborate personal approach instead of the simple, impersonal, persistent method. This is especially so when the researcher does not have prior knowledge about the population that would suggest more extensive personalization.

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Increasing Response Rates in Mailed Questionnaires: Reply

Rueben C. Buse

Commentators (Brooks et al.) argue that a response rate of 73% achieved via persistence is sufficient. They do not demonstrate this proposition in their specific example nor in the general case. They further argue that it was the homogenity of the Wisconsin population sampled and not the procedure itself which produced the high response rate. Yet, the evidence indicates the contrary.

My note was addressed to the question of nonresponse in mail questionnaires. It assumes that sampling mortality due to nonresponse is a serious source of bias in survey research and every effort should be made to secure as high a percentage of returns as possible. My purpose in writing the note was twofold. I report on a method of reducing nonresponse other than persistence, which worked well and may also work for others. Drawing the conclusion that Brooks et al. seem to find in my report would require a control group absent in both the Wisconsin and Indiana study. Based on evidence in either study, any conclusion that either personalization or persistence is preferable is at best tenuous. I had hoped to highlight the problem of nonresponse and to motivate further interest and reports of research procedures which can reduce it. There is currently little literature in the journals familiar to agricultural economists on this problem.

The commentators seemed to have missed the point. In fact, they assume that a 73% response rate is entirely adequate and that the benefit-cost ratio of further efforts to increase the response rate is low, i.e., the difference between a 73% and a 91% response rate in a heterogeneous population is not worth the costs involved. They state that "the larger no response rate in the Indiana study (27.2%) may be the price one pays when surveying heterogeneous populations." They conclude that "tentative indications from the Indiana study would suggest that personalization may not be that necessary in eliciting high response rates from the general public" (i.e., heterogeneous populations).

There is also a misconception underlying the comments. A great deal of emphasis is placed on the importance of the letter addressed to agricultural corporation presidents, implying that much of the increased response is attributable to the nature of the person to whom the study materials were addressed rather than to the procedure. The idea that the personal approach was directed to presidents of large corporations with a single community of interest, who sit in offices and delegate authority for filling out the questionnaire to a subordinate is erroneous. The commentators argue that incorporated farm presidents are more homogenous than Indiana household heads and that the prestige of the corporation president is substantial and significant to the high response rate. This is not the fact. The recipients of the letters and questionnaires are Wisconsin family farmers who have incorporated for one reason or another. In general, they are heads of households whose prestige is limited to those seated around them at the kitchen table and hence no more able to designate another to fill out the questionnaire nor any less or more homogenous as a group than the heads of Indiana households.

In the comment, 73% is assumed to be a high and adequate response rate. This may be true in the Indiana study but should not be stated as a generalizaiton. The cost of this assumption can only be calculated in terms of the validity of the conclusions since it is common knowledge that nonrespondents differ from respondents. To support the case, some evidence of the bias or lack thereof had they not had the data generated by the two follow-ups would be interesting. I submit that the differences in levels of nonresponse (27.2% in the Indiana study and 9.5% in the Wisconsin study) is substantial and should not be minimized.

The Wisconsin study found large differences in respondent waves. The efforts made to collect data from the reluctant respondent paid off in a more representative sample. The purpose of my note was to report a method to increase response rates without having to resort to dogged persistence, i.e., five or six or more follow-ups.

Had Brooks et al. used their imagination and applied some of the principles described in my note in the design of their survey, I expect their response rate may have been higher. After all, they did have the names and addresses from the auto registrations. Currently available computer software and hardware make it a very simple matter to substitute the addressee's name for "Dear Community Resident" and to individually type each letter so that it appears like a personal letter. It also seems that, from the information available in their comment, Brooks et al. are more impatient than persistent. Two follow-ups, as closely spaced as table 1 indicates, does not suggest much persistence.

Do the benefits of reducing nonresponse exceed

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the costs? The researcher must provide his own answer based on his research objectives and the nature of the population being sampled. That the authors expressed satisfaction with a 73% response rate from a heterogeneous population is surprising. Further research in this area to highlight the nature of the trade-offs and to help the researcher assess them in light of his own project is to be highly recommended. I hope the note, comment, and reply will generate more interest and careful research in this area.

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Institutional Affiliation of Authors of Contributions to the *American Journal of Agricultural Economics*—1953–1972: Comment

Robert M. Finley

Holland and Redman have given us a useful survey of the affiliation of authors who have contributed to the *Journal*. While most agree with their statement that "*AJAE* contributions . . . represent one of several important indicators of departmental quality" (p. 784), there is a disturbing element in the article. The number of printed pages may be a function both of the size and the productivity of the department. In other words, those departments with greater numbers of professional personnel might publish more in all media including the *Journal*.

In order to diminish, if not eliminate, department size as a variable, numbers of American Agricultural Economics Association members in a location, as listed in the 1972 Handbook-Directory, were compared with the pages authored. Only land grant universities were considered, and a simple count of members at the principal university city was made.[1] Admittedly, this count will not be perfect but, in general, should approximate department size both in a relative and absolute sense. It might be contended that large and/or capital cities in which a few land grant universities are located show considerable members not associated with the university. While this is valid to some extent, it is doubtful that the results would be unduly affected. Also, the extent to which the department members choose or are encouraged to join the AAEA may be an important factor affecting membership numbers for any particular location. The degree of importance that a department places on research in general and publications in particular likewise will probably influence publication in the *Journal* (and perhaps AAEA membership too).[2]

Tables 1, 2, and 3 were developed, in part, from tables 1, 2, and 3 from Holland and Redman. Only the most recent time period was used, 1968–72, in order to compare with the 1972 Handbook-Directory. In table 1 the top twenty universities for all types of papers are listed. The range was from 237 pages (Purdue) to 62.75 pages (Kansas State). However, when the ranking is made according to pages published per member, the rankings change. California-Berkeley now ranks first, followed closely by California-Davis. Other changes in position are significant. Pennsylvania State and Oregon State ranked third and fourth on a per member basis, while in total pages they ranked eleventh and ninth respectively. Purdue, Illinois, and Iowa State, the top universities in terms of total pages published, ranked ninth, sixth, and eighth, respectively, on a per member basis.

In noninvited papers (table 2), Purdue again was the top contributor with Wisconsin, Illinois, California-Davis, Iowa State, and Missouri all contributing over 100 pages in the period considered. When the noninvited category was placed on a per member basis, California-Davis was first and Wisconsin second. Pennsylvania State was third followed by Illinois, Purdue, North Carolina State, Connecticut, and Oklahoma State. Little difference was observed among Oregon State, California-Berkeley, Iowa State, Cornell, and Missouri with a range of only 0.04 page per member separating these universities.

Invited papers appeared almost as a separate population according to Holland and Redman. As shown in table 3, Minnesota, Michigan State, Illinois, Iowa State, and California-Berkeley comprised the top five in absolute numbers of pages. On a per member basis, only a few significant changes occurred. California-Berkeley ranked first with Oregon State, Minnesota, Illinois, Pennsylvania State, Iowa State, North Carolina State, and Wisconsin rounding out the top eight universities. Michigan State, Arizona, Kansas State, Missouri, and Purdue comprised the next group according to pages per member. Less than 0.1 page per member separated these five schools.

Holland and Redman cautiously suggest factors which may explain differences in invited and uninvited participation. Regional differences however,

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[1] Exceptions were Illinois and Pennsylvania State where all members from Champaign-Urbana, Illinois and University Park-State College, Pennsylvania were included with the Illinois and Pennsylvania totals.

[2] The composition of the membership in the AAEA is not known but perhaps those members listing their address as Columbia, Missouri will serve as a microcosm for the entire population. The seventy-six members from Columbia, Missouri were classified as: graduate students, 34.2%; graduate students with USDA appointment, 2.6%; graduate students with extension appointment, 1.3%; extension, 13.2%; extension with joint appointment (research and/or teaching), 10.5%; research and teaching, 13.2%; joint appointment with another department, 5.3%; other departments (no joint appointment), 5.3%; primarily administration with rank in agricultural economics, 6.6%; primarily administration without rank in agricultural economics, 1.3%; USDA, 2.6%; other and unknown, 3.9%.

Table 1. University Affiliation of Authors Contributing Papers to the *Journal*, 1968–72

University	Total Pages	Rank	Pages per Member	Rank
Purdue	237.00	1	2.39	9
Illinois	230.50	2	2.81	6
Iowa State	202.50	3	2.50	8
Wisconsin	198.25	4	3.00	5
Michigan State	180.00	5	1.58	15
Missouri	165.50	6	2.17	10
California-Davis	156.00	7	3.39	2
Minnesota	153.50	8	1.87	13
Oregon State	146.00	9	3.10	4
California-Berkeley	143.50	10	3.42	1
Pennsylvania State	143.25	11	3.18	3
North Carolina State	139.75	12	2.58	7
Cornell	137.25	13	1.99	12
Oklahoma State	106.00	14	2.00	11
Arizona	73.75	15	1.71	14
Texas A&M	73.25	16	1.56	16
Ohio State	71.75	17	1.08	19
Florida	69.07	18	1.01	20
Washington State	65.50	19	1.31	18
Kansas State	62.75	20	1.49	17

do not appear to be very important. Of the twenty schools, almost half (nine) had over 40% of their pages in the invited category. These were Minnesota, Florida, California-Berkeley, Kansas State, Oregon State, Michigan State, Arizona, Iowa State and Illinois. This constitutes a very wide geographical distribution of schools. However, only two universities ranking in the top twenty for all papers had less than 25% of their papers invited—California-Davis and Oklahoma State.

In summary, on a per member basis many schools rank similarly to their ranking in total pages published. A few notable exceptions are apparent with some dramatic changes when the per member ranking was used. While these differences are important, they may be symptomatic of the incumbency to review the amount of space in the *Journal* carefully and critically. For example, in order to be in the top twenty universities, a department had to publish only slightly over one page per member for

Table 2. University Affiliation of Authors Contributing Noninvited Papers to the *Journal*, 1968–72

University	Total Pages	Rank	Pages per Member	Rank
Purdue	162.75	1	1.64	5
Wisconsin	136.50	2	2.07	2
Illinois	136.00	3	1.66	4
California-Davis	127.00	4	2.76	1
Iowa State	116.00	5	1.43	11
Missouri	107.00	6	1.41	13
Cornell	98.25	7	1.42	12
Pennsylvania State	91.50	8	2.03	3
North Carolina State	88.75	9	1.64	6
Michigan State	83.75	10	0.73	19
Oklahoma State	80.50	11	1.52	8
Oregon State	68.25	12	1.45	9
California-Berkeley	60.50	13	1.44	10
Ohio State	47.25	14	0.72	20
Texas A&M	46.50	15	0.99	14
Washington State	39.50	16	0.79	19
Arizona	39.25	17	0.93	16
Minnesota	38.75	18	0.47	21
Tennessee	34.55	19	0.80	17
Connecticut	32.50	20	1.63	7
Maryland	32.50	20	0.98	15

Table 3. University Affiliation of Authors Contributing Invited Papers to the *Journal*, 1968–72

University	Total Pages	Rank	Pages per Member	Rank
Minnesota	114.75	1	1.40	3
Michigan State	96.25	2	0.84	9
Illinois	94.50	3	1.15	4
Iowa State	86.50	4	1.07	6
California-Berkeley	83.00	5	1.98	1
Oregon State	77.75	6	1.65	2
Purdue	74.25	7	0.75	13
Wisconsin	61.75	8	0.94	8
Missouri	58.50	9	0.77	12
Pennsylvania State	51.75	10	1.15	5
North Carolina State	51.00	11	0.94	7
Florida	46.00	12	0.68	14
Cornell	39.00	13	0.57	17
Arizona	34.50	14	0.82	10
Kansas State	34.00	15	0.81	11
California-Davis	29.00	16	0.63	15
Texas A&M	26.75	17	0.57	16
Washington State	26.00	18	0.52	18
Oklahoma State	25.50	19	0.48	19
Ohio State	24.50	20	0.37	20

the five-year period. The top school in terms of pages per member, California-Berkeley, had 3.42 pages per member for the five-year period or, in other words, the top rated school published less than 0.7 page per member per year. Even as an average, surely this is not adequate to express our views in the major medium of this profession.[3]

[3] In another article, Redman calculated that if each AAEA "member had an article of equal quality, he could *at most* have one authorship every 22 years." And since about 30% of the contributors are nonmembers, we can expect an average member to have "one authorship every 31 or 32 years" (1972, p. 146). Although Redman's figures sound pessimistic, it appears that the average member should have reason to be even more despondent. With only 3,098 pages of noninvited papers from 1968 to 1972 and slightly over 20,000 members (cumulative) for the same five-year period (Redman 1973), the average member should expect a single authorship of a ten- to thirteen-page noninvited paper every 65 to 85 years; when considering the contributions by nonmembers, the average member might expect a single authorship every 92 to 120 years.

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A Macro-Economic Model for Agricultural Sector Analysis: Errata

Derek Byerlee

Two errors in manuscript preparation have raised questions about the interpretaton of equations (4) and (8). In equation (4), $X_j^*(t)$ is the exponentially lagged value of the rate of change of the output of the jth sector and not the value of the output of the jth sector (pp. 523–24). In equation (8), $C(t)$, $I(t)$, and $E(t)$ are vectors of domestic consumption, capital good demands, and exports, respectively, not the total values defined on p. 524.

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Byerlee, Derek, and A. N. Halter. "A Macro-Economic Model for Agricultural Sector Analysis." *Amer. J. Agr. Econ.* 56 (1974): 520–33.

Publications

Books Reviewed

Cochrane, Willard W. *Agricultural Development Planning*. N.Y.: Praeger Publishers, 1974, xii + 223 pp., price unknown.

> Implementing a plan of economic development is like fighting a long war. Many people get hurt in the process, frustrations and failures are commonplace, and the patience of people is sorely tried. (P. 160)

> The planning process is a many-sided process in which the government assumes the responsibility for dealing with a multitude of development problems, large and small, that are all demanding in terms of information requirements, integration requirements, skilled staff, and budget. In this context it is difficult, if not impossible, to build a plan organization and operating procedures in accordance with an inner logic; plan organization and operating procedures in each country seem to grow, rather, as a sprawling, shapeless mass in response to urgent, diverse problems. The magnitude, the diversity, and the urgency of development problems in one country after another spawn an organization and a set of operating procedures unique to each country that are more concerned with solving an immediate problem than with producing a consistent, efficient development plan with the capacity to bring about sustained and balanced development. (Pp. 162–3)

These two statements, occurring as they do only two pages apart in the text, go a long way in characterizing the complexity of the planning process and the problems associated with it. Having made such statements, lesser souls would have turned tail and run—to find something less forbidding. But Cochrane takes it as his goal to understand the complexity of the planning process as it relates to agriculture. In his words, "It was the ubiquity of the state of affairs described above across the less developed world that prompted the writing of this book." He hoped that a clear perception of what planning is, what it can do, and what it cannot do with respect to the agricultural sector, would improve the art and practice of development planning in the agricultural sector.

The central thesis of the study is that development planning in the less developed world should be limited in concept and application and should be concerned only with those kinds of activities that the market does poorly or not at all. The author suggests that planning be limited to three sets of activities: (*a*) the provision of physical and social infrastructure, (*b*) the pursuit of policies designed to induce private parties to produce and consume in changed ways and combinations, and (*c*) the pursuit of policies and programs designed to reduce real income inequities among the population. The production and distribution of consumer goods, as well as intermediate goods, he suggests, should be left to the direction of the market. He enjoins the less developed countries to plan around the edges of the economy, concentrating on those tasks that are absolutely essential, and depend on the market to do the rest.

This book is a potpourri, perhaps best characterized by its subtitle: Economic Concepts, Administrative Procedures, and Political Process. Its range is great, extending from a survey of the state of knowledge regarding agricultural development, to conceptualization of the planning process, to detailed prescriptions of how to plan, to an evaluation of the planning process in three countries that have had considerable planning experience. The book suffers from a very uneven level of discourse. On one page the reader is exposed to an almost trite description of what is needed to do effective planning, while a few pages later he is given perceptive insights into political process and economic policy. For those who are willing to trudge through the low spots, however, there are many insights and perceptions from one who has had a rich and productive career.

The book is well organized and for the most part lucidly written. It deals primarily with the basics and will be of value to beginning students of the planning process and to members of the bureaucracy. Certainly, the reader who perseveres will have a healthy appreciation of the complexity of the planning process.

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Council of Economic Advisers

Gordon, Wendell. *Economics from an Institutional Viewpoint*. Austin: University Stores, 1973, ix + 389 pp., $5.95.

Gordon has written a profound—albeit complex—book, a book not to be considered in the same league with the spate of texts for teaching "basics" or "principles." This comprehensive book focuses on institutional economics; the contrast between the institutional approach and that of present orthodoxy is clearly shown. The book is dedicated to Clarence E. Ayers, the late economist from the University of Texas believed by many to be the last giant of institutional economics. In the preface, Gordon challenges the economics profession "to do some serious soul searching." For example, he criticizes some of the present forecasting models, quite correctly, for attempting to predict a dependent variable while independent variables are changing more rapidly than the dependent variable.

In times of crisis we review (or at least should review) the systems of economics, economic maxims, and theories of other eras. Many times these have been laid aside and judged to be inappropriate for a modern setting. Just as Keynes reached back to the mercantilists to support parts

of his theory, we, too, might do well to review and recall some of the writings of the institutionalists. Very early in the book, the question is posed: "Do students, on the average, tend instinctively not to believe pure-competition theory and general-equilibrium theory anyway, even though Nobel Prizes are given for work in this area?" (p. iv). But Gordon writes not to dispute national income analysis and price theory but to reconcile these with institutional theory and to show that these perspectives are not completely incompatible. He does indicate that "a little head-knocking" may be in order and insists that economics should be taught as a social science and not as a branch of mathematics.

The core of institutional theory based on Ayers, Dewey, Commons, and Veblin is presented early in a logical and succinct manner. The next consideration is value theory and here the critical question is asked: Does society want a welfare maximum? The feasibility and compatibility of raising the welfare of the underprivileged and remaking the affluent society into a civilized and pleasant place are examined in a brief but readable manner.

An adequate-to-good discussion of the standard analytical tools is presented early, e.g., elasticities, growth patterns, etc. The standard methodologies of economics are compared and examined and found to be lacking:

> Almost nobody, to this day, has really a good word to say as to the accuracy of the estimates [of demand and supply elasticities]. . . . Maybe it is just that the 'game is so much fun'—and similarly for the over-refinement of and the constancy claims for the standard Keynesian propensities.
>
> Decision making is a complicated process that requires general social agreement on goals and a viable democratic process in which society as a whole has the final word. (P. 98).

An alternative way of viewing the economic process is presented as a downstream flow of a river as compared to the circular flow usually used.

The section on comparative economic systems is unusual and bears reading in detail. It is flawed only in that it is limited to several aspects of several systems rather than a broader spectrum and that it seems out of place in the flow of the book.

Of particular interest to the noninstitutionalist is the study of institutional economics in the "proper" frame of reference. According to the author, institutional economics is a theory of economic progress and a value theory. Conceptualizing institutional behavior is seen as one of the most difficult tasks of the economist. Still, until and unless such behavior is captured in our models, results will be of little use at best and dangerous at worst.

Even though Gordon makes a good case for free trade, he expressly points out that the argument for free trade is not an argument for laissez faire and pure competition as regulators of the economy. Free trade, it is thought, will interfere with the human freedom of action as little as possible. Job protection is discounted as a restraint of trade; instead a policy of free trade with adequate job guarantees is urged. Impediments to free trade are viewed as poor devices for increasing production and consumption. Also, lack of free trade may well lead to decreasing production and consumption and incite international animosities.

A theory of economic development well worth considering is set forth. Those institutions which may be facilitating or inhibiting influences in economic development are outlined. Consumption habits are to some degree an institution, a product of our cultural conditioning. All wants are social phenomena, the product of social conditions. As Veblin contended that consumption was peculiarly conditioned by the system of status, our wants are thus affected, at least initially, by institutional and technological considerations. The author is openly critical of some types of technical assistance.

> Advice offered by the foreign adviser is frequently inappropriate, even obviously inappropriate. [The adviser] is compelled to say something, to solve a problem instantaneously, and yet he may not have been in the area long enough to be especially conversant with the unique local climate and soil conditions or the unique local ideas about diet. . . . The farmer who is instinctively suspicious of the advice anyway . . . may genuinely know there is something wrong with it. And the advising procedure is discredited. Advice by transient experts hardly represents the millennium as a device in transmitting technology. (P. 302)

These words are hardly calculated to comfort many of those engaged in economic development and technical assistance. In sum, Gordon is not negative but only pessimistic regarding "traditional" means of economic development.

Boulding has warned against limiting graduate students "to the fashions of the present" which lead us "into a tight little intellectual box from which there is no escape" and further laments that "it is a sad commentary on the American scene in economics that the only really indigenous American school of economists, the institutionists, represented for instance by John R. Commons of Wisconsin, left only a handful of descendants" (p. 156).

Other than some of those Wisconsin-trained agricultural economists, it is difficult to list a large number in our profession who evince evidences of institutionalism. My colleagues, Harold Breimyer and Jim Rhodes of Missouri and Bert Evans of Nebraska, come immediately to mind but the list is still short—very short.

As valuable as this book potentially is, unfortunately it probably will not have wide acceptance. It does have major flaws. No index is included and the footnotes and references are placed in the text almost as if they were there for the convenience of

the author, not the reader. (Footnotes are interspersed within the text and not numbered.) Also (at least in my copy) page vi, a part of the table of contents, is missing.

Gordon writes with the fervor and urgency of a man with much to say who intends to "tell all." Sometimes this detracts, but in the main the absence of an air of self-approval is most refreshing. Other items could be listed as distractions and omissions but *aliquando bonus dormitat Homerus* ("sometimes even the good Homer nods").

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Nelson, Aaron G., Warren F. Lee, and William G. Murray. *Agricultural Finance.* 6th ed. Ames: Iowa State University Press, 1973, ix + 413 pp., $11.50.

Agricultural Finance is the sixth edition of a college textbook first published by Murray in 1941 and substantially revised with the addition of each coauthor, Nelson in 1960 and Lee in 1973.

The original text reflected the concerns and attitudes of most agricultural finance analysts after two decades of farm depression. It became entrenched as the profession's "standard" text without serious competition for the next three decades. But as debt repayment problems failed to develop in the 1950s as they had after previous wars, agricultural finance interests and approaches shifted markedly. The text followed, though not without metamorphic difficulties.

Murray in 1941 defined agricultural finance as "a study in the main of the borrowing of funds by farmers, . . . divided into two parts: credit principles and lending organizations." This organizational format was retained through the fifth edition. Thus, relative lack of attention to noncredit aspects of financial management was discerned as the text's weak point from the very first, and the major revisions—other than factual updating—were largely attempts to add such material.

At first, this deficiency was regarded as a relatively mild malady. Butz in 1942 was content to note that "perhaps such questions should properly be treated in a book on farm management, but . . . inclusion of an additional chapter on this phase of agricultural finance would have made the treatment of the subject more complete." By 1961, Diesslin protested more strongly that "the title . . . remains a misnomer" because the text "touches too lightly on some of the important aspects of financial management." Subsequent years saw especially large advances in conceptualization and empirical analysis of farm financial management, particularly in the context of multiperiod growth models. Nelson and Murray in 1967 responded by adding a chapter on the subject; however, John Lee detailed how their failure to cut loose from the traditions of preceding editions prevented the text from reflecting the "new and innovative changes . . . reshaping the financial structure of the farm sector." In his view, this would require "development of a system of analysis that has management of financial resources to achieve alternative financial goals as the central theme, and analyses of alternative ways of acquiring financial resources as integral parts of the system." Implicitly, in view of "the natural temptation to use earlier editions as a starting point," the once mild flaw now seemed terminal: "What is needed is a fresh start."

It is thus noteworthy that the authors of the sixth edition have, in essence, brought off this difficult feat. Concepts, terminology, and quotations cherished through five previous editions have been purged. Substantively, a key step was to divorce the discussions of risk and cash and income flows from their former context as "guides in use of credit," freeing them for roles in the treatment of farm financial management generally. Equally important, the new presentation of financial goals, growth, leverage, risk, insurance, and estate planning competently reflects the conceptual and research literature that has evolved since 1960 at a level that appears appropriate for the advanced undergraduate student.

These topics require a lengthy string of chapters. At its conclusion, perhaps a synthesizing chapter would have been helpful to make clear and to illustrate the simultaneity of these considerations in the making of financial management decisions. Along the same line, the material on estate transfer planning might have been located within that string of chapters to emphasize the need for consideration of this element as each major financial decision is made or new stage of the firm life cycle is entered. The chapters on credit instruments and lenders' procedures that now intervene break a desirable train of thought.

The concluding portion of the text, which treats the characteristics and policies of various farm lender groups, has also been modernized by inclusion of a general discussion of financial markets and intermediation. Unfortunately, modeling and empirical investigation of this area are barely under way, and current thinking should perhaps be labeled more clearly as conjecture rather than analytical conclusions. For instance, it remains to be determined whether rural-urban differences in the level and behavior of interest rates do or do not result primarily from serious imperfections in financial markets, as the authors state. In other words, it is not yet known whether the net effect of all market imperfections is to keep funds from flowing into or out of rural areas.

The newly added discussion of monetary policy seems appropriate for today's world. Students, however, may be misled or confused when trying to analyze future events while guided by statements such as "when . . . inflationary pressures are developing and the rate of growth in the supply of money should be restricted, the Open Market Committee sells securities, which . . . reduces member bank reserves" (p. 297). In fact, at such times, the Federal Reserve System is most likely to be buying securities and adding to reserves at an average rate at least, since this action suffices—in the face of relatively high demand for loans and money—to produce "tight money" conditions and sharply higher interest rates.

Both in this chapter and in that on commercial banks, the discussion is flawed by multiple references to the effect that banks can make additional loans only if they have excess reserves. At no cost in simplicity of exposition and with considerable gain in terms of insight into modern banking practices and into the implementation of monetary policy, it should instead have been noted that most banks (and the banking system as a whole) have operated with no excess reserves for some years. Banks make desired additional loans by marketing their assets or liabilities—in particular by marketing certificates of deposit. Such action by banks in the aggregate increases required reserves. If the Federal Reserve System supplies reserves at a rate roughly matching this desired rate of expansion in money and credit, monetary policy will appear neutral and interest rates will tend to be stable. If it supplies reserves at a faster rate, policy will be easing and money market interest rates will be forced downward (other things being equal); conversely, if reserves are supplied at a slower rate, policy will be tightening and money market rates will be moved upward. Discussion in these terms would also lead to greater appreciation of the problem presented by current variations in the ability of banks of different sizes to market their liabilities—one of the major imperfections in our financial markets.

Finally, if one asks what major element of domestic agricultural finance research remains slighted in the new text, it is clearly the study of cycles and trends in the aggregate demand for inputs such as fertilizer, machinery, and buildings, in land prices and the rate of land transfers, and more generally in the aggregate flow of funds. With the financial outlook publications of the Department of Agriculture now cast in this framework, it would be useful to cover the concepts and uses of aggregate flow-of-funds accounts, models, and estimators, as well as the major analytical findings of this work.

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O'Connor, Robert. *Principles of Farm Business Analysis and Management*. Shannon: Irish University Press, 1973, xvii + 442 pp., £ 5.00.

This book, by an Irish author, is mainly about farm accounts and planning. "Management" refers to farm business management rather than any technical aspects of managing a farm. "Farm business analysis" refers to methods of examining the farm business including farm accounting, comparative analysis, and budgeting. Other topics covered include production economics, farmers' prices, farm borrowing, and the economics of specific enterprises.

The book consists of an introduction, six sections, and a mathematical appendix. Each of the sections is divided into one or more chapters. The introduction deals with managerial processes, the environment in which farm business decisions are made, and how farm records and analysis can help supply the information that a farmer must have if he is to make good decisions.

Section 1 gives an overview of the principles of production economics. The presentation is practically oriented and is illustrated by data taken mainly from Iowa experiments. Among the principles discussed are the law of diminishing (marginal) returns, substitution of inputs, and substitution of enterprises. Section 2 presents an elementary treatment of price determination and the concept of elasticity. Also discussed are production cycles and seasonality and their effects on prices. The mathematical appendix at the end of the book offers an algebraic treatment of some of the concepts presented in sections 1 and 2.

Section 3 contains three chapters and deals with the keeping and analysis of farm accounts. A distinction is made between farm level financial records and enterprise cost accounts. Using two example farms, a step-by-step description is given of how farm accounts are kept and summarized. The summarized accounts are then used to systematically test the efficiency of the farm business. Testing is facilitated by the use of selected efficiency factors, calculated from the basic data, which are compared with standards from farms of similar size and type.

Section 4, which deals with farm planning, also contains three chapters. In this book, farm planning is synonymous with budgeting. Topics covered in-

clude partial budgets, complete budgets, gross margin planning, capital budgets, and investment appraisal. Linear programming is treated in considerable detail. A worked example is used to illustrate the method of program planning and the results are compared with complete budgeting using the trial and error method. An illustrative example of full-scale linear programming using the simplex method is also presented.

Section 5 focuses on farm borrowing. Capital rationing is a serious problem in farming where both average rate of return on investment and capital turnover are low. Though the average return is low, the margin may often be high particularly on short-term working capital. Borrowing capacity of farmers and sources of farm credit in Ireland are also discussed. The economics of specific enterprises under Irish conditions is the subject of section 6. Enterprises examined are cattle, milk, and sheep; pigs and poultry; and cash crops.

Overall, the book is well written and has good continuity. Its strength lies in the many insights and observations that result from the author's experience in collecting and analyzing farm records. Its weaknesses are those of omission and, for some readers, its Irish orientation.

The introduction explains the management function within a farm environment. By identifying the role of farm records and analysis in the manager's decision-making process, the stage is set for the remainder of the book.

Sections 3 and 4 are the heart of the book. Here, concepts are well presented, e.g., systems of accounts (p. 91), terms used in farm accounting (p. 100), investment appraisal (p. 193), and partial and complete budgets (p. 171). The step-by-step approach used to show procedural methods is also excellent, e.g., keeping financial accounts (p. 98), using accounts to test efficiency (p. 135) and program planning an example farm (p. 213). The use of real life example farms lends practicality to sections 3 and 4 and provides a continuity from record keeping to analysis to planning. Pitfalls for the unwary are highlighted, as the author promised to do, and suggestions are offered on how to avoid them, e.g., gross margin planning (p. 186), objections to the linear programming method (p. 205), and some general observations on interpretation of farm accounting results (p. 167).

Conspicuous by its absence is any mention of computerized farm accounting systems. Similarly ignored is the movement in many countries towards a national system of farm accounts. Computerized farm planning packages, particularly of the decision aid category such as feed mix, are also omitted. The use of farm records for purposes other than management, e.g., tax, credit, or monitoring government programs, receives scant attention in this book.

Sections 1 and 2 are useful because they provide a theoretical background for material later in the book. Production economics principles are adequately covered, well illustrated, and their practical applications shown. Price determination is also adequately treated as are the concepts of elasticity and production and price cycles in agriculture. The mathematical appendix is also, by and large, useful.

The same can hardly be said of sections 5 and 6. For the Irish reader, section 6 contains much information on the economics of specific enterprises. For the North American reader it simply does not apply. Section 5 on farm borrowing partly falls into the same category but the first half contains a good discussion of the return on capital in farming, capital turnover, and the borrowing capacity of farmers.

In summary, this book is a useful addition to the literature on farm management in general and farm accounting, analysis, and planning in particular. To an Irish audience it can be recommended in its entirety to "students of farm business management in agricultural schools, colleges, and universities," perhaps even to "educated farmers" (p. xv). To a North American audience, sections 3 and 4 are recommended to students, teachers, research and extension workers in farm accounting, analysis, and planning. The introduction, sections 1 and 2 and the mathematical appendix may be found useful. A word of warning: though their meaning will often be clear from the context, there are many Irish terms to decipher.

Joseph F. Guinan
Canfarm, Agriculture Canada

Books Received

Brown, Lester R. *In the Human Interest*. N.Y.: W. W. Norton & Co., 1974, 190 pp., $6.95.

Brown, Lester R. with **Erik P. Eckholm.** *By Bread Alone*. N.Y.: Praeger Publishers, 1974, xi + 272 pp., $8.95, $3.95 paper.

Chenery, Hollis, Montek S. Ahluwalia, C. L. G. Bell, John H. Duloy, and **Richard Jolly.** *Redistribution with Growth*. N.Y.: Oxford University Press, 1974, xx + 304 pp., $16.00, $4.50 paper.

Conner, Richard J., and **Edna Loehman,** eds. *Economics and Decision Making for Environmental Quality*. Gainesville: University of Florida Press, 1974, x + 299 pp., $12.50.

Correa, Hector. *Population, Health, Nutrition, and Development*. Lexington, Mass.: D. C. Heath Co., 1975, xvii + 226 pp., $21.50.

DeCanio, Stephen J. *Agriculture in the Postbellum South*. Cambridge: MIT Press, 1974, xii + 335 pp., $15.00.

Fletcher, W. W. *The Pest War*. N.Y.: Halsted Press, 1974, x + 218 pp., $11.95.

Geithman, David T. *Fiscal Policy for Industrialization and Development in Latin America*. Gainesville: University of Florida Press, 1974, x + 370 pp., $12.50.

Haefele, Edwin T. *The Governance of Common Property Resources*. Baltimore: Johns Hopkins Press, 1974, 181 pp., $7.50.

Hunter, John M., and **James W. Foley.** *Economic Problems of Latin America*. Boston: Houghton Mifflin Co., 1975, xii + 390 pp., $13.95.

International Bank for Reconstruction and Development. *Education Sector Working Paper*. Washington, D.C., 1974, ii + 73 pp., free.

Isard, Walter. *Introduction to Regional Science*. Englewood Cliffs, N.J.: Prentice-Hall, 1975, xxii + 506 pp., $11.95.

James, Sydney C. *Workbook for Farm Accounting and Business Analysis*. Ames: Iowa State University Press, 1975, 112 pp., $3.95.

James, Sydney C., and **Everett Stoneberg.** *Farm Accounting and Business Analysis*. Ames: Iowa State University Press, 1975, viii + 269 pp., $7.95.

Johnson, Arnold H., and **Martin S. Peterson.** *Encyclopedia of Food Technology*. Westport, Conn.: Avi Publishing Co., 1974, xv + 993 pp., price unknown.

Johnston, Bruce F., and **Peter Kilby.** *Agriculture and Structural Transformation*. N.Y.: Oxford University Press, 1975, xi + 474 pp., $6.95.

Jones, Dave. *The Western Horse; Advice and Training*. Stillwater: University of Oklahoma Press, 1974, viii + 175 pp., $6.95.

Kazarian, Edward A. *Food Service Facilities Planning*. Westport, Conn.: Avi Publishing Co., 1975, vii + 230 pp., price unknown.

Lippit, Victor D. *Land Reform and Economic Development in China*. White Plains, N.Y.: International Arts & Sciences Press, 1975, xi + 183 pp., $15.00.

LonČarević, Ivan. *Die Kooperation zwischen den privaten landwirtschaftsbetrieben und den gesellschaftlichen Wirtschaftsorganisationen in der Landwirtschaft Jugoslawiens*. Berlin: Duncker & Humblot, 1974, 203 pp., price unknown.

Lynch, Robert E., and **John R. Rice.** *Computers; Their Impact and Use*. N.Y.: Holt, Rinehart & Winston, 1975, xi + 398 pp., price unknown.

Merkel, James A. *Basic Engineering Principles*. Westport, Conn.: Avi Publishing Co., 1974, vii + 204 pp., price unknown.

Merrill, William C., Lehman B. Fletcher, Randall A. Hoffmann, and **Michael J. Applegate.** *Panama's Economic Development: The Role of Agriculture*. Ames: Iowa State University Press, 1975, xi + 219 pp., $6.95.

Oppenheimer, Harold L., and **Stephen K. Weber.** *Cowboy Securities: Going Public in Agriculture*. Danville, Ill.: Interstate, 1975, xiii + 548 pp., price unknown.

Pantastico, Er. B. *Postharvest Physiology, Handling and Utilization of Tropical and Subtropical Fruits and Vegetables*. Westport, Conn.: Avi Publishing Co., 1975, xiv + 560 pp., price unknown.

Pollard, E., M. D. Hooper, and **N. W. Moore.** *Hedges*. N.Y.: Taplinger Publishing Co., 1975, 256 pp., $14.95.

Ryall, Lloyd A., and **W. T. Pentzer.** *Handling Transportation and Storage of Fruits and Vegetables*. Westport, Conn.: Avi Publishing Co., 1974, xi + 545 pp., price unknown.

Shallenberger, R. S., and **G. G. Birch.** *Sugar Chemistry*. Westport, Conn.: Avi Publishing Co., 1975, xiii + 221 pp., price unknown.

Shoemaker, James S. *Small Fruit Culture*. Westport, Conn.: Avi Publishing Co., 1975, vii + 339 pp., price unknown.

Snodgrass, Milton M., and **L. T. Wallace.** *Agriculture, Economics, and Resource Management*. Englewood Cliffs, N.J.: Prentice-Hall, 1975, xi + 521 pp., $13.95.

Thiede, Günther. *Europas Grune Zukunft—Die Veränderung der ländlichen Welt. (Europe's Green Future—A Rural Revolution)* Econ-Verlag: Dusseldorf und Wien, 1975, 464 pp., 38.- DM.

Voorhis, Jerry. *Cooperative Enterprise*. Danville, Ill.: Interstate, 1975, x + 239 pp.

Wadekin, Karl-Eugen. *Sozialistische Agrarpolitik in*

Osteuropa. Berlin: Duncker & Humblot, 1974, 238 pp., price unknown.

Wallerstein, Immanuel. *The Modern World System*. N.Y.: Academic Press, 1974, xiv + 410 pp., $16.50.

Wells, Hutchins A. *Water Rights Laws in the Nineteen Western States*. Washington, D.C.: Economic Research Service, U.S. Department of Agriculture, 1974, xxx + 756 pp., price unknown.

Wells, Jerome C. *Agricultural Policy and Economic Growth in Nigeria, 1962–1968*. N.Y.: Oxford University Press, 1975, xviii + 490 pp., $18.00.

Whiting, Larry R., vol. ed. *Communities Left Behind: Alternatives for Development*. Ames: Iowa State University Press, 1974, x + 151 pp., $4.95.

Winkler, A. J., James A. Cook, W. M. Kliewer, and **Lloyd A. Lider.** *General Viticulture*. Berkeley: University of California Press, 1975, xx + 710 pp., $27.50.

Woodroof, Jasper Guy, and **Frank G. Phillips.** *Beverages: Carbonated and Noncarbonated*. Westport, Conn.: Avi Publishing Co., 1974, ix + 526 pp., price unknown.

News

Announcements

Name Change

The name of the Department of Economics at North Carolina State University has been changed to the Department of Economics and Business.

1975 Winter Meeting

The American Agricultural Economics Association will meet jointly with the Allied Social Sciences Associations in Dallas, December 28–30. The agenda for the three sessions in which the AAEA will be participating is as follows.

National Food Policy for an Interdependent and Uncertain World
(joint session with the American Economic Association)

Chairman: Luther Tweeten, Oklahoma State University
Speakers: Hendrick S. Houthakker, Harvard University, "Do Consumers or the Nation Need a National Food Policy?"; Gary L. Seevers, Commodity Futures Trading Commission, "Impact of Policy Alternatives on the Food Sector and Its Performance"
Discussants: Daryll E. Ray, Oklahoma State University; Howard W. Hjort, Schnittker Associates, Washington, D.C.

Financial Responses to Agricultural Market Risks
(joint session with the American Finance Association)

Cochairmen: C. B. Baker, University of Illinois; Merton Miller, University of Chicago
Speakers: Paul Cootner and Roger Gray, Stanford University, "Risk Management in Agricultural Commodity and Financial Markets: Methods, Distribution, Rewards, and Structural Effects"; Peter Barry and Donald Fraser, Texas A&M University, "Risk Management in Primary Agricultural Production: Methods, Distribution, Rewards, and Structural Effects"
Discussants: To be announced

Organization, Efficiency, and Performance in Socialist Agriculture
(joint session with the American Economic Association and the Association for Comparative Economic Studies)

Chairman: Arcadius Kahan, University of Chicago
Speakers: D. Gale Johnson, University of Chicago, "A Model of Socialist Agricultural Firms"; Anthony M. Tang, Vanderbilt University, "Organization and Performance in Chinese Agriculture"; Zbigniew Fallenbuchl, University of Windsor, "Incentives and Organization of East European Agriculture"; Roy Laird, University of Kansas, "Economics and Politics in the Organization of Socialist Agriculture"
This session will be conducted as a panel discussion at which copies of the papers will be available for the audience. An additional panelist or so may be added.

Personnel

Agricultural Development Council

Appointment: Harlan C. Lampe, on leave from the University of Rhode Island, is working on ways to improve education in fisheries economics in Southeast Asia, June–December.

University of California

Appointments: James W. McFarland, former assistant professor of resource economics, University of Rhode Island, is on the staff of the Los Alamos Scientific Laboratory, New Mexico; **Odell L. Walker,** on leave as professor of agricultural economics, Oklahoma State University, is at the University of California-Davis beginning in July.

University of Chicago

Appointment: D. Gale Johnson is vice president and dean of faculty.

Clemson University

Appointment: R. Lynn Harwell, at work on a Ph.D. at Oklahoma State University, is an assistant professor of agricultural economics and rural sociology with extension farm management responsibilities.

Cornell University

Appointments: David Blanford, Ph.D. University of Manchester, and **H. O. Mason,** Ph.D. University of California–Davis, are assistant professors of agricultural economics; **G. Parthasarathy,** on leave as head of the Department of Cooperation and Applied Economics, Andhra University, Waltair, India, is a visiting research fellow, 1974–75; **C. Peter Timmer,** formerly with Stanford University, is the Babcock Professor of Food Economics.
Retirement: Clifton W. Loomis, former department extension leader and professor of farm management, has left after twenty years of service.
Honor: Max E. Brunk, professor of marketing, gave a series of Klinck Lectures across Canada sponsored by the Agricultural Institute of Canada, March 19–April 3.

University of Illinois

Appointment: Steven T. Sonka is an assistant professor of agricultural economics.

Iowa State University

Appointment: John A. Miranowski is an assistant professor of economics.
Resignation: Treena K. Levins, former research associate in economics, has left effective March 14.

Kansas State University

Appointment: Roe Borsdorf, former assistant director, Marketing Division, Kansas Department of Agriculture, is an assistant professor of agricultural economics, international projects.
Honor: C. Dean McNeal, group vice president, Pillsbury Company, Minneapolis, received the Agricultural Economics 1975 Distinguished Alumnus Award from the Department of Economics.

Michigan State University

Appointment: Harold Ecker, formerly with the Institute of Agricultural Technology, is a professor and will both teach and direct the elevator and farm supply program.

University of Minnesota

Appointments: Vernon R. Eidman, formerly with Oklahoma State University, is a professor in production economics and farm management; **William J. Young,** M.S. University of California-Davis, is a research specialist in resource economics.
Retirement: E. Fred Koller, former professor of agricultural and applied economics, has left after forty-five years of service.

University of Nebraska

Appointment: Bruce Johnson, Ph.D. Michigan State University, is an assistant professor of resource economics.

University of New Mexico

Appointment: Ronald G. Cummings, former professor and chairman of resource economics, University of Rhode Island, is a professor of economics.

North Carolina State University

Appointment: Richard S. Fenwick, Jr., former ex-

tension agricultural economist, Kansas State University, is an associate professor of economics and business.
Leave: **Richard K. Perrin** is working in Mexico.
Return: **J. A. Seagraves** is back from Peru.

Oklahoma State University

Appointments: **Loren Parks,** at work on a Ph.D. at the University of California-Davis, and **Joseph E. Williams,** at work on a Ph.D. at Iowa State University, are assistant professors of agricultural economics.
Retirement: **K. C. Davis,** former professor of agricultural economics, has left after thirty-eight years of service.

Oregon State University

Appointment: **Carl W. O'Connor,** former assistant professor of economics, Iowa State University, is an assistant professor of economics.

Purdue University

Appointments: **Wilmer A. Dahl,** assistant professor of agricultural economics, is teaching and counseling in the food sales and distribution associate degree program; **Joseph Goodwin** is a temporary assistant professor in agricultural economics working on the Brazil Research Loan Project; **James K. Whittaker** is an assistant professor of agricultural economics and production economics.

University of Rhode Island

Leave: **Niels Rorholm** will use his 1975–76 sabbatical to study coastal resource use conflicts along the U.S. east coast.

Texas A&M University

Appointments: **Bruce Beattie, Richard Shumway, J. Michael Sprott,** and **John Steele** are associate professors of agricultural economics; **Beto Brunn** and **James Casey** are research associates in agricultural economics; **Stephen Fuller, Hovav Talpaz,** and **Robert Whitson** are assistant professors of agricultural economics; **Donald Levi** is an associate professor of agricultural law; **James Mallet** is an economist; **Irvin May** is a research historian at the Texas Agricultural Experiment Station; **Vernon Schneider** is the Roy B. Davis Distinguished Professor of Agricultural Cooperation; **Ron Weddel** is a research economist.

U.S. Department of Agriculture[1]

Appointments: **Ronald J. Glass,** formerly with NRED, Upper Darby, Pennsylvania, is with the Forest Service, Juneau, Alaska; **L. Thad Horne,** formerly with NRED, Little Rock, Arkansas, is with the Forest Service, Ogden, Utah; **Howard Osborn,** formerly with NRED, is with the Agricultural Research Service; **Jasper Womach,** formerly with NRED, is with the Soil Conservation Service.
Appointment in CED: **V. Eldon Ball** is with the Meat Animals Program Area.
Appointments in EDD: **Milburn D. Childs** is with the Great Plains Research Project, Enid, Oklahoma; **Donald D. Steward** is acting assistant director.
Appointment in FDD: **John T. Larsen** is on a temporary assignment in Nairobi, Kenya for two years.
Appointments in NEAD: **Laura Blanciforti,** formerly with Data Resources, Lexington, Massachusetts; **Donald Lee Hinman,** B.A. Colorado College, is with the Economic Projections Program Area; **Robert D. Reinsel** is the leader of the Inputs and Finance Program; **Erhardt Rupprecht,** M.A. American University, is assisting on a Congressional study relating to transportation in rural America; **Lloyd Douglas Teigen,** formerly with the Korean Agricultural Sector Simulation Project, Seoul, Korea, is with the Projections Program Area.
Appointments in NRED: **Richard T. Clark** is at the University of Nebraska; **Douglas Lewis; Joe McKeown** is in Little Rock, Arkansas; **Fred T. Stewart** is at the University of Florida.
Resignation in CED: **Robert J. Reierson.**

University of Wisconsin

Appointment: **Richard N. Weigle** is statewide program leader for agriculture and agribusiness.
Honor: **Douglas A. Yanggen** received one of the U.S. Department of Agriculture's superior service awards for 1975 for his work relating renewal and protection of inland lake resources in Wisconsin.

Other Appointments

Raymond E. Borton, formerly an Agricultural Development Council associate in the Philippines, is with Resources Development Associates.
Robert I. Coltrane, formerly with EDD, is project area leader of Manpower Services.
James Wesley Davis, M.S. Purdue University, is a farmer in Clayton, Indiana.
R. Samuel Evans, Ph.D. Virginia Polytechnic Institute and State University, is with Engel Shipbuilding Company, Pascagoula, Mississippi.

[1] **CED:** Commodity Economics Division of Economic Research Service; **EDD:** Economic Development Division of ERS; **FDD:** Foreign Development Division of ERS; **NEAD:** National Economic Analysis Division of ERS; **NRED:** Natural Resource Economic Division of ERS.

Ralph Hepp is with the Federal Extension Service studying the role of cooperatives for limited resources farms.

Joseph H. Gill, M.S. Purdue University, is a county extension agent in Lafayette, Indiana.

Richard Terry Keith, formerly with the University of Arkansas, is with the Red River Production Credit Association, Texarkana, Arkansas.

Richard E. Maxwell, M.S. University of Arkansas and formerly with Wellens & Company, is with the Federal Intermediate Credit Bank, St. Louis.

Walter G. Miller, formerly with EDD, is a staff economist at the Office of Program and Policy Planning, U.S. Department of Transportation.

Arlo J. Minden, formerly at Purdue University, is with the Agency for International Development.

David C. Nelson, formerly at North Dakota State University and with the Southern University-Agency for International Development Cameroon Project, is dean of the Faculty of Business, Industry, and Applied Programs, Moorhead State College, Moorhead, Minnesota.

Roger M. Perry, formerly at the University of Arkansas, is with the Federal Land Bank, Jonesboro, Arkansas.

Gordon C. Rausser, on leave as professor of economics, Iowa State University, will be a visiting professor at Harvard University, 1975–76.

J. J. Richter, on leave as professor of agricultural economics and rural sociology, Iowa State University, is at the Institute of Agricultural Policy, University of Bonn, Germany and with the European Economic Community, Brussels, Belgium.

Larry J. Schluntz, formerly with NRED, is with the Bureau of Reclamation, U.S. Department of the Interior.

J. William Uhrig, on leave from Purdue University, is a research associate with Cook Industries, Memphis, Tennessee.

Gary D. Walker, M.S. University of Arkansas, is with the U.S. Army Corps of Engineers, Vicksburg, Mississippi.

John Shipley Young, M.S. Purdue University, is vice president of Melrose Farms, Herndon, Kentucky.

Obituaries

Fred F. Lininger

Fred F. Lininger, former head of the Department of Agricultural Economics and director of the Agricultural Experiment Station at Pennsylvania State University, died at Gettysburg, July 22, 1974, one week prior to his 82nd birthday.

Lininger's long and varied career of service to agriculture began in 1917 as a county agent following his graduation from Penn State. He served later as the supervisor of vocational agriculture at Morrison Cove Vocational School in his native Blair County, Pennsylvania. From 1923 to 1925, he was that state's director of vocational agriculture. In 1926, he was appointed an assistant professor in Penn State's relatively new Department of Agricultural Economics, where he advanced through the associate and professor ranks to become department head in 1938. On leave in 1933–34, he served with the Brookings Institution in Washington. In 1941, he accepted the position of vice dean and director of the Pennsylvania Experiment Station; a year later he became director of the station. He held that post until 1952 when he retired with the rank of director emeritus.

Lininger continued to be professionally active for many years following his retirement from Penn State, primarily in duties associated with the Food and Agricultural Organization of the United Nations which he had served as an agricultural consultant during leaves prior to retirement. Service with FAO included five years at its headquarters in Rome; for three years he was deputy director of the Agricultural Division. He then accepted a two-year assignment in Ceylon. Following his FAO experiences, he taught as a visiting professor at the University of Florida and spent a year and a half at the University of Mandalay in Burma.

Born in Martinsburg, Pennsylvania, July 29, 1892, Lininger received the B.S. degree from Penn State in 1917 and did his graduate work at Cornell University receiving the M.S. degree in 1926 and his Ph.D. in 1928. He was a member of the American Farm Economics Association, the International Conference of Agricultural Economists and a number of professional, scientific, and honorary fraternities. In 1917, he married Mildred Tobias who lives now in Gettysburg. Also surviving are a son, Fred T., senior vice-president of the International Bank of Washington, D.C., a daughter, Mrs. Charles H. Taylor, Jr., of Maple Glen, Pennsylvania and four grandchildren.

Robert E. Schneidau

Robert Emil Schneidau, 40, professor, Purdue University, died April 20, 1975, of a heart attack. Schneidau was born November 2, 1934 in Chicago. He was reared there and in Kokomo, Indiana. Having completed his high school work at Kokomo, he attended Purdue University, receiving his B.S. degree in 1956, his M.S. in 1958, and his Ph.D. in 1963. He joined the Purdue staff in 1961, where he distinguished himself working primarily in agricultural marketing. In 1971, he was a visiting professor, Oregon State University.

Bob Schneidau was always a teacher. His students were varied and many. His classroom teaching was innovative and respected. Students sought him out.

Schneidau was an Army veteran and a member of First Baptist Church. He belonged to many professional organizations, including AAEA, Sigma Xi, national scientific honorary, and Epsilon Sigma Phi, national agricultural honorary. Bob Schneidau championed the common man. He was widely known for this work with managers of small- and medium-sized livestock businesses. He had recently pioneered new marketing innovations designed to help preserve competition for all in pricing livestock. He published widely.

Bob had a delightful wit and zest for life. These probably showed best in his skills as an amateur magician. He gave generously of this talent to many individuals and groups. He died after collapsing during a fascinating performance at a special benefit magic show at West Lafayette High School.

He was a professional. His supervisors were always barraged by testimony to this from students, farmers, businessmen, colleagues throughout Purdue University, other university personnel in this country and abroad, government administrators, and county agents. Someone at Purdue heard almost daily from a new beneficiary of his help.

He was married in 1953 to Joan Dugan. She survives with four sons, Stephen Robert, of Lafayette; Randall Emil, Timothy Alan, and Jeffery David, all at home; a daughter, Cynthia Joan, at home; parents, Dr. and Mrs. George Schneidau, of Clearwater, Florida; and a sister, Mrs. Henry (Barbara) Swarzak of Rockville, Maryland.

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June 1975

For further information, please contact

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Information on Submitting Manuscripts

1. **Cover letter.** In a cover letter to the editor, the author must state (*a*) that the material has not been published, and is not being published or being considered for publication elsewhere; (*b*) that the material in the manuscript, so far as the author knows, does not infringe upon other published material protected by copyright; and (*c*) that he or she is aware that each issue of the *Journal* is copyrighted, that submission of a manuscript to the *Journal* gives the AAEA the right to publish and to copyright the material, and that republication elsewhere at a later date is contingent upon written approval from the *Journal* editor. If the applicability of point (*a*) is unclear, the author should provide an explanation of the publication status of the manuscript.
2. **Author's identification.** In order to protect their anonymity in the review process, authors should avoid identifying themselves in the manuscript. Attach a separate page including the names of the author(s) and appropriate biographical information, as well as the title of the manuscript. Include only the title on the first page of the text.
3. **Typing.** Double-space all material, including footnotes, tables, quotations, and references, on 8½-by-11-inch standard weight white paper with margins on all sides of at least 1¼ inches.
4. **Style.** Follow *A Manual of Style* by the University of Chicago Press as well as previous issues of this *Journal*.
5. **Mathematical notation.** Use only essential mathematical notation; such notation is costly to typeset and may limit the readership. Avoid using the same character for both superscripts and subscripts, using capital letters as superscripts or subscripts, and using overbars, tildes, carets, and other modifications of standard type. Asterisks, primes, and small English letter superscripts are suitable substitutes.
6. **Footnotes.** Number footnotes consecutively throughout the paper, not page by page. Type the footnotes, double-spaced, on a page following the article. The institutional paper number and acknowledgments, if any, should be placed at the beginning of the list of footnotes. Footnotes should be only explanatory and should not be used for citations or for directing the reader to a particular work. This information can be incorporated into the text itself.
7. **References and citations.** Place all references, alphabetized by author, in a list at the end of the paper entitled "References." Only cited works should be included in the reference list. All citations should appear in the text and contain the author's name and page numbers, when necessary. Citations can be inserted parenthetically, e.g., (Doe) or (Doe, p. 5). Specify the date of publication if the same author appears more than once in the reference list, e.g., (Doe 1971, p. 5). If the author's name appears as part of the sentence, a parenthetical reference is unnecessary unless you need to cite page numbers or a date. A style sheet on references and citations is available upon request.
8. **Tables.** Place each table on a separate page; double-space all material; omit vertical rules.
9. **Figures.** Prepare figures on heavy white paper or acetate sheeting using black India ink or paste-up types suitable for black and white reproduction by a photographic process. Typescript is not suitable.
10. **Three copies.** Send the typed original and two carbon copies or photocopies. All copies should be inspected for completeness and quality of reproduction.
11. **Review by colleagues.** Authors are strongly urged to have their manuscripts critically reviewed by their colleagues prior to submission.
12. **Abstract.** Instructions for the preparation of an abstract will be sent when the manuscript is accepted for publication.
13. **Page Charge.** All published contributions, with certain specific exemptions, are subject to a charge of $40 per printed page or fraction thereof. Exemptions from the charge will be made for authors who certify in writing that no financial support exists from an employer or granting agency to cover the payment. Exemptions are also granted for book reviews, papers invited by the AAEA president, papers invited by the editor, the presidential address, and the fellow's lecture. Payment information and details on the financial exemption statement are provided with galley proofs. One hundred reprints (without covers) are provided if the charge is honored.

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Objective

The AAEA seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy. The activities of the AAEA include:

—publishing the *American Journal of Agricultural Economics;*
—planning and conducting two annual meetings of the membership;
—sponsoring annual awards for outstanding extension programs, distinguished teaching, and outstanding research;
—recognizing outstanding agricultural economists through a fellows program;
—publishing the *American Bibliography of Agricultural Economics* and supporting an associated retrospective literature search in cooperation with the U.S. Department of Agriculture;
—publishing periodically a biographical directory of the AAEA's members;
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